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RESEARCH SUMMARY

Weights and volumes of downed woody material in diameter classes of one-fourth to 1, 1 to 3, and greater than 3 inches and forest floor duff depths were summarized from extensive inventories in northern Idaho and Montana. Biomass loadings are shown by cover types and habitat types within National Forests. Total downed woody biomass east of the Continental Divide ranged from 5 tons per acre in ponderosa pine to 23 tons per acre in spruce-fir. West of the divide, loadings range from 13 tons per acre in ponderosa pine to 33 tons per acre in cedar-hemlock. Duff depths for cover types ranged from 0.5 to 1.5 inches or approximately 10 to 25 tons per acre. Sixty percent of biomass greater than 3 inches diameter displayed some decay. Inasmuch as 10 tons per acre is considered desirable for on-site retention, spruce-fir and larch-grand fir cover types had the greatest excesses of biomass for utilization. Relationships proved ineffectual for predicting loading from stand age, slope, aspect, and elevation. Loadings generally increased with increased productivity, but varied greatly with stand age. The generality that dead fuels tend to become predictably high in overmature stands, but unpredictable in young immature and mature stands was supported. Forest fuel succession is discussed in relation to tree mortality, fuel buildup, and depletion.

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United States
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**Intermountain
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Experiment Station**

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Downed Dead Woody Fuel and Biomass in the Northern Rocky Mountains

James K. Brown
Thomas E. See

INTRODUCTION

Downed dead woody fuel and biomass consists of dead twigs, branches, stems, and boles of trees and shrubs that have fallen and lie on or near the ground. To land managers, downed dead woody material is both a benefit and detriment. It is beneficial as a source of nutrients in the ecosystem, shelter and food for wildlife, soil stabilization, shade for young trees, fuel for useful purposes, and forest products. It is detrimental when excessive amounts accumulate causing unwanted wildfire hazards, obstructions to people and wildlife, and a tieup of nutrients.

Knowledge of downed woody material quantities can be used in such activities as determining stand prescriptions, evaluating possibilities for utilization of firewood, pulpwood, and other products, and appraising fuel and fire behavior potentials. For example, in determining stand prescriptions, knowledge as to whether excessive or deficient quantities of downed woody material are expected can aid in managing fuels and in setting target amounts of woody material to be left on site. Consideration should be given to maintaining favorable microbial populations for long-term site quality (Harvey and others 1979), needs of wildlife (Thomas 1979), grazing opportunities, wildfire hazards, and to other factors having either a positive or negative impact. Although evaluation of these factors may be highly judgmental, knowledge of woody quantities can faciliate communications and decisions in the planning process.

This paper reports on quantities of downed woody material found in western Montana and northern Idaho and examines the predictability of accumulated dead biomass. The information on downed woody quantities is based on inventories conducted by the Forest Service Region 1 (Northern Region) over a 6-year period. The terms "biomass" and "fuel" and the concept of fuel accumulation and succession are discussed next to help in understanding the findings from this study. Findings are reported in two major sections, Loading and Volume Summaries and Loading and Stand Relationships.

FUEL ACCUMULATION AND SUCCESSION

The concepts of fuel accumulation and succession are important in establishing fuel management strategies; so an understanding of them is desirable. General usage of "fuel accumulation" implies an increase in fuel loading and associated fire hazard over time. The term often is loosely used but the concept is of considerable concern to land managers. A countermeasure to "fuel accumulation" involves deterioration and decay. Fuel succession refers to change in fuel properties, such as loading, size distribution, and live-to-dead ratios, and embodies the concepts of both accumulation and decay.

"Forest biomass" and "forest fuels" both refer to vegetation, but the two terms frequently refer to different amounts of plant material. Biomass refers to total weight of vegetation. In the absence of disturbances, biomass increases predictably with time because photosynthesis is perpetual. Forest fuel is organic material that could contribute to combustion. In this sense, only certain kinds and parts of vegetation are fuels. The amount of vegetation that is available for combustion depends on such factors as fuel size, moisture content, and arrangement. In most forest fires, some vegetation is unavailable for combustion; for example, most of the biomass produced on a forest site is frequently tied up in standing tree boles and is unavailable except where fuels are ideally arranged. This can cause confusion because seldom is all vegetation available for combustion. The terms "forest fuels" and "biomass" are often used synonymously.

Live and dead fuels, as well as small and large fuels, can follow different successional patterns. Live fuels can be divided into two groups: (1) crown fuels consisting of foliage and fine branches and (2) surface fuels consisting of grasses, forbs, and shrubs. Coverage and biomass of herbaceous vegetation and shrubs appear to increase during development of some stands and to decrease in others. Increases and decreases apparently depend on site conditions and species existing before disturbance (Lyon and Stickney 1976; Habeck 1976), as well as on

the nature of disturbance. On mesic sites, biomass of herbs and shrubs tends to peak during early stages of stand development and to decrease after that.

Once crown canopies are closed, loadings of fine dead fuels, such as foliage, bark flakes, and twigs and stems less than about 1.0 inches (2.5 cm) in diameter, remain fairly constant in the forest floor litter layer (Jeske and Bevins 1979). Small oscillations in loading occur (Fahnestock 1976). This pattern appears logical because dead needles and leaves are shed annually along with some live and dead twigs. Variable production of foliage and varying wind and snow effects probably cause the oscillations in loading.

Dead branches and tree boles accumulate on the ground in response to natural causes of mortality and factors causing downfall (Brown 1975). Causes of mortality such as fire, insects, disease, suppression or natural thinning, and wind and snow damage impact stands in a rather haphazard manner. Thus, buildup of downed dead biomass also occurs in a haphazard manner and is not necessarily related to stand chronology.

SOURCE OF DATA

In 1972, the Forest Service Region 1 incorporated procedures for inventorying downed woody material into their forest inventory program. This publication is based on data collected over a 6-year period from 1972, and was made possible by a system of edited data records stored on magnetic tape. Downed woody material was estimated using the planar intersect method described by Brown (1974a) and Brown and Roussopoulos (1974) and included in the Stand Examination Handbook (USDA Forest Service Region 1 1978). The handbook provided for estimation of the following fuel variables:

1. Loading of 0.25- to 0.99-inch (0.6- to 2.5-cm) material;
2. Loading of 1.0- to 2.99-inch (2.6- to 7.5-cm) material;
3. Loading of 3.0-inch (7.6-cm) and greater sound material;
4. Loading of 3.0-inch (7.6-cm) and greater rotten material; and
5. Depth of forest floor duff (02 horizon, also called F and H layers of the forest floor, which is everything beginning at the bottom of the loosely cast litter layer to the mineral soil; the 01 horizon or litter layer is excluded).

Material less than 0.25 inch (0.6 cm) in diameter was not inventoried. The size classes correspond to standard timelag moisture response categories (Fosberg 1970) used especially in the National Fire-Danger Rating System (Deeming and others 1977). Rotten material includes downed pieces that show rot visibly on the outside. The planar intersect method furnished direct estimates of volumes that were converted to weights assuming the following densities:

Fuel	Density (lb/ft^3)
0.25 to 0.99 inch	30
1.0 to 2.99 inches	25
3.0 inches and greater:	
Sound	25
Rotten	19

Inventoried fuel data were gathered under two sampling plans:

1. *Forest inventory (stage 1).* — This inventory is conducted for timber management planning on a Forest-wide basis (Stage and Alley 1972). Sample plots are located on a 5 by 10 chain grid in randomly chosen management subcompartments. Each sample point represents 5 acres. Over several years, all National Forests in Region 1, underwent a forest inventory. Nearly all Forest Service land outside of classified wilderness was sampled. Because sample areas were randomly chosen, inventory summaries are representative of Forest-wide conditions.

The Coeur d'Alene (now part of the Idaho Panhandle), Beaverhead, and Lewis and Clark National Forests were inventoried without fuel measurements and the Custer National Forest data were unavailable to us. Thus, for these Forests, loading summaries from the Forest Inventory were not possible in this report. The Colville National Forest, now in Region 6 (Pacific Northwest Region), but formerly in Region 1 (Northern Region), was inventoried and appears in this report.

2. *Stand examination (stage II).* — This inventory is conducted for project activities, such as timber sale preparation, forest thinning, and restocking surveys. Plots are systematically located in stands that individual Ranger Districts select for management activities. Thus, this inventory is biased toward those stands. Although the kind of stands sampled varies by Ranger District, most examinations are conducted in anticipation of timber sales.

Many stands selected for timber sales are "high risk"; a large amount of mortality is expected before the next rotation. In stands considered "high risk," some mortality has already occurred and downed woody fuels may have accumulated above normal amounts.

The goal for sampling precision is to locate enough plots to provide a standard error of the estimate of timber volume within 20 percent for stands less than 20 acres in size and within 15 percent for larger stands. Those goals are not always met.

In conducting stand examinations, fuel information is not always collected. It is more often collected for timber sale and thinning preparations than for restocking surveys. For this study, only fuel information recorded on the timber management form (R1-2410-15B, 4/75) was analyzed. Large amounts of fuel data have also been collected on the fire management form (R1-5100-07), but were not centralized on data tapes for ready access.

For both the Forest Inventory and Stand Examination, sampled fuels were, for the most part, naturally occuring rather than slash. On many Forests, considerably less than 25 percent of the Forest Inventory data came from cutover areas as shown in the following tabulation:

National Forests	Percent sample points in cutover photo interpretation classes
Kootenai, Flathead, Colville	24
Lolo, Bitterroot	17
Clearwater, Kaniksu, St. Joe, Deerlodge, Helena	7
Custer, Gallatin, Nezperce	1.5

In using the fuel summaries reported here, the difference between the Forest Inventory and Stand Examination data can

have important implications. The key distinction is that the Forest Inventory data represent Forest-wide stand conditions; whereas, the Stand Examination data primarily represent stands selected for timber harvesting and, to a lesser extent, thinning. Discussions with Range District timber personnel indicated that a large proportion of stands selected for timber sale were "old growth" or "high risk."

Analysis was directed at preparation of tables summarizing fuel loadings by National Forests and at examining the relationships between loadings and stand descriptors, such as cover type, habitat type, age, aspect, elevation, and site productivity. For the summary tables, the Forest Inventory data were pooled by cover types and habitat types. Sample statistics were computed for fuel characteristics from the pooled data. For the Stand Examination data, mean fuel characteristics were computed by stands. Because stand selection was biased, data were not pooled by cover types and habitat types but evaluated on a stand basis.

Relationships between fuel characteristics and stand descriptors were analyzed using the Forest Inventory data because it represented a random sample that was free from known bias. In investigating relationships, fuel characteristics were treated as stand means and number of plots per stand were used as weights.

LOADING AND VOLUME SUMMARIES

Forest Inventory

Loadings of downed woody material and duff depth were summarized by cover types and by habitat type groups. Readers who are interested in statistics for individual National Forests should turn to appendix I. Variation in the data and correlations between fuel variables are discussed in appendix II. The following main text presents summaries for groups of National Forests, such as those east of the Continental Divide (Eastside) and west of the Continental Divide (Westside). Total loading is the sum of the 0.25- to 0.99-inch (0.6- to 2.5-cm), 1.0- to 2.99-inch (2.6- to 7.5-cm), and over 3-inch (7.6-cm) downed woody material. For convenience, downed woody material less than 3 inches (7.6 cm) in diameter will be referred to as small fuel, and downed woody material 3 inches and greater will be referred to as large fuel. For proper application of these summaries, remember that they describe downed woody biomass accumulated primarily in the absence of harvesting and thinning.

Cover types. — Cover types conform to USDA Forest Service standard forest survey types. Cover types were named for the species representing a plurality of basal area in a stand. The following cover types were encountered in either the Forest Inventory or Stand Examination with sufficient data to merit summary:

C-H	Cedar-hemlock	*Thuja plicata* Donn- *Tsuga heterophylla* (Raf.) Sarg.
DF	Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
L	Larch-grand fir	*Larix occidentalis* Nutt.- *Abies grandis* (Dougl.) Lindl.
LP	Lodgepole pine	*Pinus contorta* Dougl.
PP	Ponderosa pine	*Pinus ponderosa* Laws.
S-F	Spruce-subalpine fir	*Picea engelmannii* Parry- *Abies lasiocarpa* (Hook.) Nutt.
WP	Western white pine	*Pinus monticola* Dougl.

Habitat type groups. — Loadings of downed woody material were not expected to vary significantly between many habitat types. However, loadings were expected to vary by groups of habitat types that reflect a gradient in moisture and temperature. Thus, the habitat types described by Pfister and others (1977) were grouped into the following categories for relating to loading:

1. Limber pine (*Pinus flexilis*); ponderosa pine, and Douglas-fir/bunch grass types.
2. Dry site Douglas-fir and moist site ponderosa pine.
3. Moist site Douglas-fir.
4. Cool sites dominated by lodgepole pine; dry, lower elevation subalpine fir.
5. Moist site, lower elevation subalpine fir.
6. Cold, moist site upper elevation subalpine fir.
7. Warm, moist sites; mostly cedar-hemlock.

The habitat type fire groups developed by Davis and others (1980), based on similarity of tree succession, were used as a basis for grouping habitat types in this paper. The habitat types comprising these groups and their correspondence to the fire groups developed by Davis and others (1980) are shown in appendix III. (The last page of this document lists the common name, scientific name, abbreviation, and ADP code for each habitat type mentioned in this publication.)

Generalities and comparisons. — Total downed woody loadings from moist, productive sites tend to be greater than from drier, less productive sites as shown in figures 1 and 2. The cedar-hemlock type supported the greatest loading followed by spruce-fir. Ponderosa pine displayed the smallest loading (fig. 3). Eastside Forests consistently have smaller loadings than Westside Forests with one minor exception in habitat type Group Three.

Total loadings vary more among cover types than among habitat type groups as seen in comparing figures 1 and 2. This seems reasonable because downed woody material accumulates almost entirely from trees; shrubs contribute only slightly to downed woody material. Cover types more accurately reflect tree species occupying sites than habitat types. Tree species influence downed woody accumulations to the extent that tree size and susceptibility to mortality relate to species.

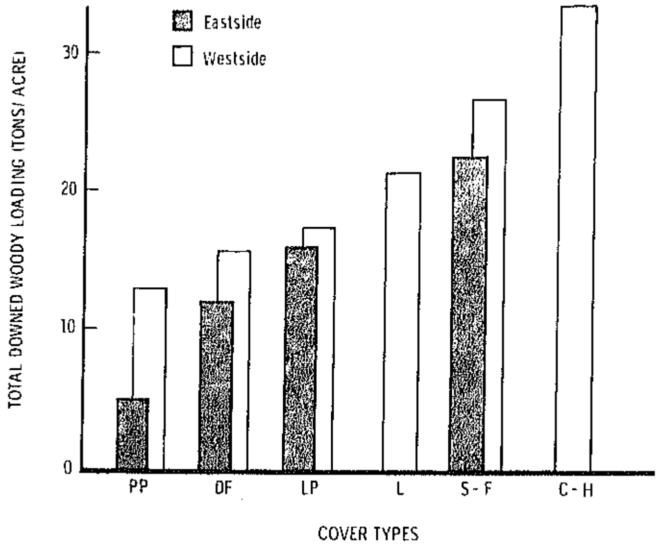

Figure 1. — Total downed woody loadings by cover type for Westside and Eastside National Forests.

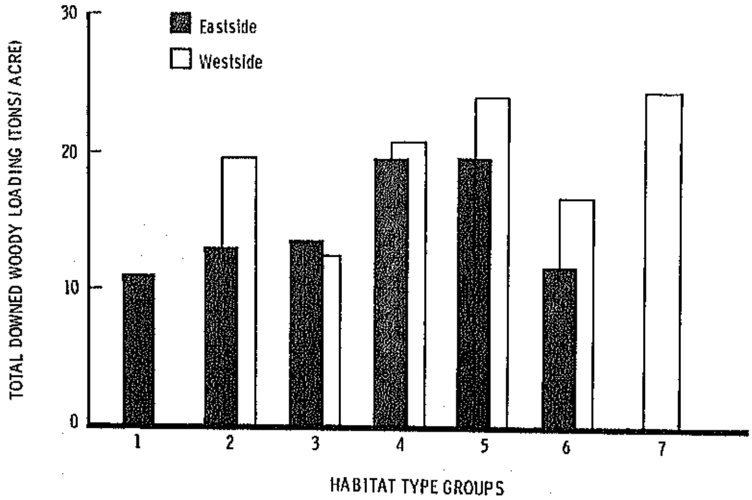

Figure 2. — Total downed woody loadings by habitat type group for Westside and Eastside National Forests.

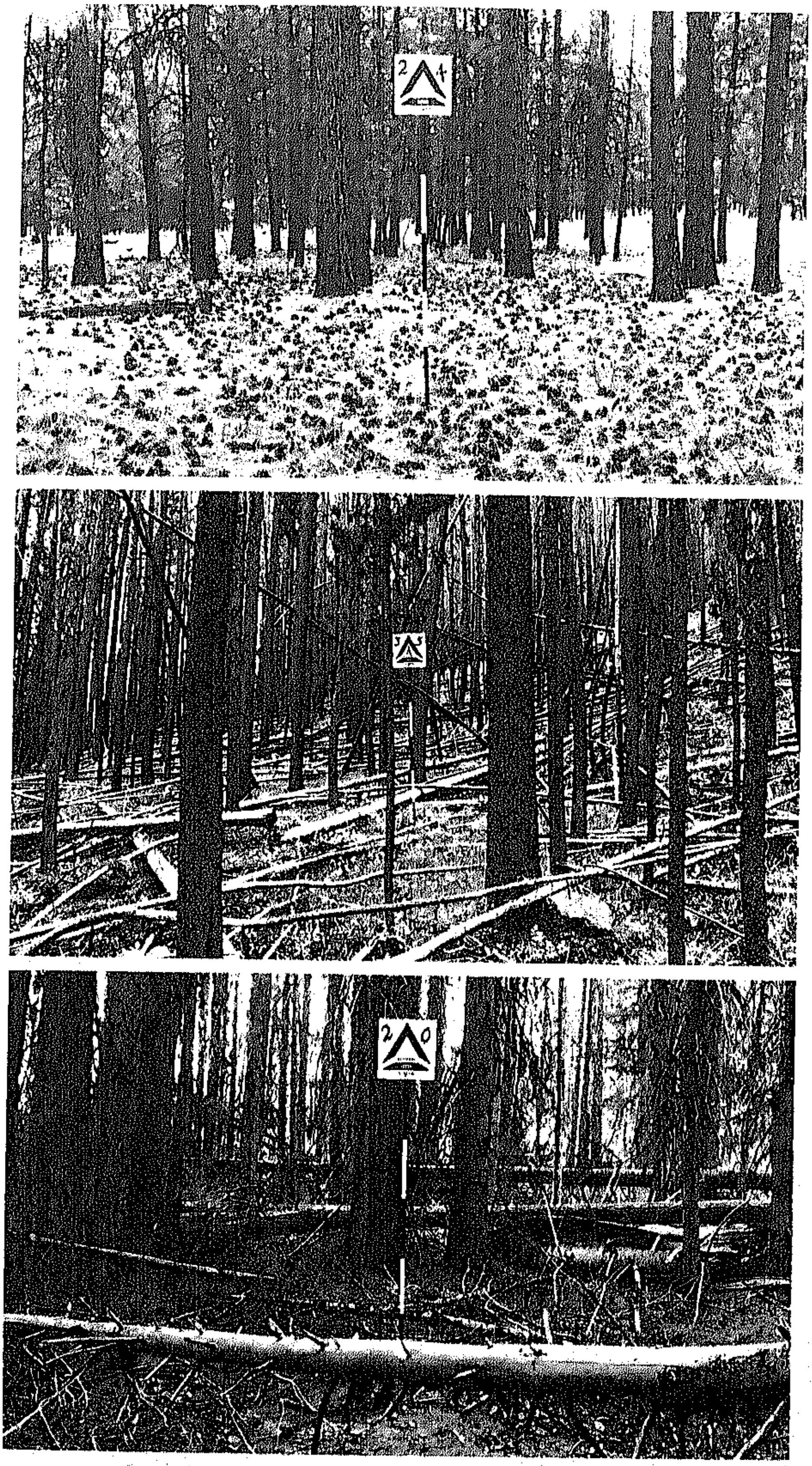

Figure 3. — Loadings of total downed woody material varied widely as illustrated: 1 ton/acre in a ponderosa pine stand (top); 12 tons/acre in a lodgepole pine stand (middle); and 40 tons/acre in a spruce-fir stand (bottom).

Small downed woody material did not vary greatly among cover types and among habitat type groups (tables 1 and 2). Considering an additional loading for 0- to 0.25-inch (0- to 0.6-cm) material, which should be small compared to the 0.25- to 3-inch (0.6- to 7.5-cm) material, loadings of less than 3-inch (7.6-cm) material can be expected to average from 3 to slightly over 4 tons/acre (0.67 to 0.90 kg/m²) for all forest types.

Duff depths averaged about 0.5 to 1.5 inches (1.3 to 3.8 cm). Assuming a bulk density of 8 lb/ft³ (0.13 g/cm³), these depths correspond to loadings in the neighborhood of 10 to 25 tons/acre (2.2 to 5.6 kg/m²). Cover types and habitat type groups having the greatest total downed woody loadings also have the greatest duff depth (tables 1 and 2).

Percent rotten displayed little difference among cover types and habitat type groups (tables 1 and 2). Considering the imprecise method for classifying sound and rotten material and the variation in percent rotten among stands, a figure of 60 percent rotten is a reasonable estimate representing all forest types. During field inventories, degree of rot was not measured. Thus, estimates of percent rotten include pieces showing only a small amount of surface decay to pieces entirely in a decayed, crumbly state.

Table 1.—Average downed woody loadings, duff depths, and percentages rotten from the Forest Inventory by cover type and National Forest, Westside and Eastside

Cover type[1]	Westside Forests: Number observed	Westside Downed woody: Small	Large	Total	Duff depth	Rotten large	Eastside Forests: Number observed	Eastside Downed woody: Small	Large	Total	Duff depth	Rotten large
		Tons/acre	Tons/acre	Tons/acre	Inches	Percent		Tons/acre	Tons/acre	Tons/acre	Inches	Percent
PP	944	2.5	10.4	12.9	0.6	61	184	1.1	3.9	5.0	0.6	70
DF	5,762	2.8	12.9	15.7	.9	63	2,475	2.4	9.6	12.0	1.0	63
LP	4,172	3.1	14.4	17.5	1.1	59	3,400	2.2	13.9	16.1	1.1	55
L	5,381	3.6	17.7	21.4	1.2	58	—	—	—	—	—	—
S-F	3,597	2.9	23.8	26.7	1.4	52	712	2.5	20.2	22.7	1.3	52
C-H	1,727	4.0	29.4	33.4	1.4	57	—	—	—	—	—	—

[1]PP = Ponderosa pine, *Pinus ponderosa* Laws.
DF = Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco.
LP = Lodgepole pine, *Pinus contorta* Dougl.
L = Larch-grand fir, *Larix occidentalis* Nutt.-*Abies grandis* (Dougl.) Lindl.
S-F = Spruce-subalpine fir, *Picea engelmannii* Parry-*Abies lasiocarpa* (Hook.) Nutt.
C-H = Cedar-hemlock, *Thuja plicata* Donn-*Tsuga heterophylla* (Raf.) Sarg.

Table 2.—Average downed woody loadings, duff depths, and percentages rotten from the Forest Inventory by habitat type group and National Forest, Westside and Eastside

Habitat type groups[1]	Westside Forests: Number observed	Westside Downed woody: Small	Large	Total	Duff depth	Rotten large	Eastside Forests: Number observed	Eastside Downed woody: Small	Large	Total	Duff depth	Rotten large
		Tons/acre	Tons/acre	Tons/acre	Inches	Percent		Tons/acre	Tons/acre	Tons/acre	Inches	Percent
1	—	—	—	—	—	—	577	2.3	8.5	10.8	1.1	66
2	2,569	3.6	15.9	19.5	0.8	54	1,234	2.5	10.5	13.0	1.0	59
3	3,287	2.4	10.0	12.4	.9	54	1,151	2.1	11.3	13.4	.9	59
4	5,348	3.2	17.3	20.5	1.1	56	2,320	2.4	17.0	19.4	1.2	56
5	3,937	2.8	21.0	23.8	1.4	53	870	1.9	16.9	18.8	1.0	54
6	474	2.1	14.3	16.4	1.0	48	123	2.1	9.4	11.5	.7	57
7	5,460	3.6	20.3	23.9	1.3	57	—	—	—	—	—	—

[1]1. = Limber pine *(Pinus flexilis)*; ponderosa pine and Douglas-fir/bunch grass types.
2. = Dry site Douglas-fir and moist site ponderosa pine.
3. = Moist site Douglas-fir.
4. = Cool sites dominated by lodgepole pine; dry, lower elevation subalpine fir.
5. = Moist site, lower elevation subalpine fir.
6. = Cold, moist site upper elevation subalpine fir.
7. = Warm, moist sites; mostly cedar-hemlock.

Figure 4 is presented for quick reference to total loadings and for comparing total loadings among Forests. Few generalities are apparent in figure 4 except that the ranking of Forests according to loading differs among cover types. For example, the Colville N.F. displays the highest loadings by far for the cedar-hemlock, spruce-fir, and ponderosa pine cover types; yet, loadings for larch-grand fir and Douglas-fir have middle rankings. Variation in cedar-hemlock loadings is greater than in other types. The reasons for variation among Forests are not apparent from simply examining the inventory summaries. However, knowledge of stand histories would probably explain most of the real differences among Forests.

The diameters of large fuel were analyzed on a sample of commonly occurring habitat types usually associated with cover types of Douglas-fir, western larch, lodgepole pine, cedar-hemlock, and spruce-fir. Results showed that on the average, large fuels have greater diameters in larch, cedar-hemlock, and spruce-fir cover types than in Douglas-fir and lodgepole pine cover types (fig. 5). Diameters of large fuels run greater on Westside than on Eastside Forests. For example, the percentage of large fuels greater than 10 inches (25.4 cm) in diameter is:

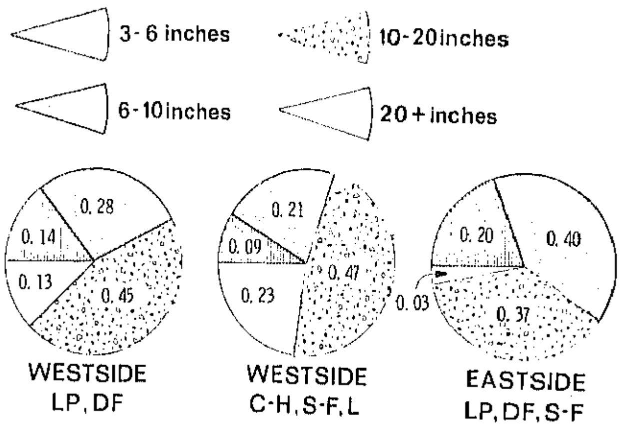

Figure 5. — Fractions of large fuel by diameter class for selected cover types on Eastside and Westside National Forests.

Location and cover type	Percentage
Westside; C-H, S-F, L	70
Westside; DF, LP	58
Eastside; S-F, DF, LP	40

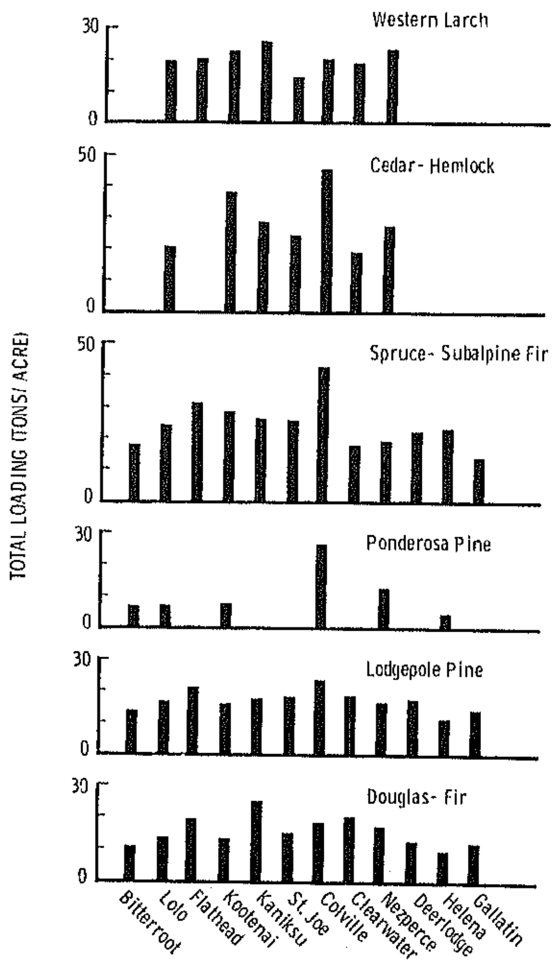

Figure 4. — Total downed woody loadings by cover type and National Forest.

A greater fraction of large fuels over 10 inches in diameter is rotten rather than sound probably because large pieces remain decayed for a larger period than small pieces. Considerable variation existed among Forests in the fractional breakdown of large fuel diameters. This could be important in applying large fuel information; thus size distribution summaries by individual Forests are shown in appendix IV.

Stand Examination

Loadings of downed woody material from Stand Examinations are summarized in appendix V for individual National Forests. The ranking of cover types according to total loadings and duff depth is the same for both Stand Examination and Forest Survey data. The cedar-hemlock type supported the greatest loadings followed in order by spruce-fir, larch, Douglas-fir, lodgepole pine, and ponderosa pine.

Loadings from Stand Examinations ranged from about the same as the Forest Inventory (representative of Forest-wide conditions) to as much as three times greater (table 3). Ratios of 1.0 indicate that stands selected for Stand Examinations contain loadings similar to average loadings for the whole Forest. Ratios highlighted in table 3 indicate Forests and cover types where stands selected for Stand Examinations tended to be high risk or decadent and to contain substantially greater loadings than the average Forest stand.

On the Bitterroot and Clearwater National Forests, Stand Examinations especially appear to have been located in high-risk stands. On most Forests, Stand Examinations in the ponderosa pine cover type displayed markedly greater loadings than the Forest Survey average for ponderosa pine. Several reasons could explain this; one possible explanation is, however, that harvestable ponderosa pine stands have undergone considerable mortality leading to an accumulation of downed woody material that is about double the Forest-wide average.

The Stand Examination data offer another approach to extrapolating loadings. If high-risk or decadent stands are of interest, the factors in table 3 can be multiplied times the loadings in appendix I. This should provide better estimates of loadings in high-risk stands. The estimates should, however, be regarded as rough approximations because the representativeness of Stand Examinations is known only generally.

Because Stand Examinations are conducted to provide information on stands identified for certain management activities, extrapolation of Stand Examinations summaries to other areas is risky without knowledge of the Forest conditions where the Stand Examinations were taken. Persons acquainted with the location of Stand Examinations may be able to understand and to make use of Forest Survey as well as Stand Examination summaries. To help explain where Stand Examinations were located, the number of stands sampled by the National Forest and the Ranger District are tabulated in appendix V.

Volumes

Because volumes rather than weights may be of interest, particularly for evaluating utilization potentials, table 4, summarizing volumes per acre of woody material over 3 inches (7.6 cm) diameter by cover type, is presented. Volumes were calculated from the loadings in appendix I assuming 60 percent rotten

Table 3.—Ratios of mean total downed woody fuel loadings from Stand Examination data to Forest Inventory data. Shading indicates substantial high-risk stand conditions where loadings are substantially greater than average forest conditions

National Forests	Cover types[1]					
	DF	PP	S-F	C-H	L	LP
Bitterroot	2.3	2.0	3.1			2.1
Lolo	1.1	1.7	1.7		1.1	1.2
Flathead	1.0		1.2		1.0	.7
Kootenai	1.2	3.2	1.1	1.2	1.3	1.0
Clearwater	1.3		1.8	2.2	1.8	1.2
Nezperce	1.2	2.0	1.4	1.4	1.3	1.0
Panhandle	1.2		1.2	1.4	1.4	1.0
Helena	2.0	1.0	1.3			1.3
Deerlodge	1.0		1.2			.9
Gallatin	1.5		1.7			1.5

[1]DF = Douglas-fir.
PP = Ponderosa pine.
S-F = Engelmann spruce-subalpine fir.
C-H = Western redcedar-western hemlock.
L = Western larch-grand fir.
LP = Lodgepole pine.

Table 4.—Volumes of large downed woody material by cover type and National Forest from the Forest Inventory

National Forest	Cover types[1]					
	DF	PP	S-F	C-H	L	LP
	ft³/acre					
Bitterroot	880	500	1,530			1,160
Lolo	1,090	460	2,000	1,700	1,610	1,270
Flathead	1,620		2,720		1,720	1,780
Kootenai	1,040	560	2,470	3,390	1,980	1,370
Clearwater	1,510		1,390	1,460	1,500	1,400
Nezperce	1,380	1,020	1,680	2,180	2,100	1,410
Kaniksu	2,070		2,330	2,450	2,340	1,310
St. Joe	1,130		2,140	2,080	1,180	1,480
Colville	1,440	2,170	3,650	3,910	1,620	1,820
Helena	790	370	2,030			990
Deerlodge	1,010		1,940			1,500
Gallatin	970		1,140			1,130
Westside	1,230	990	2,260	2,840	1,680	1,360
Eastside	910	370	1,920			1,320
Western Montana	1,110	510	2,290	3,130	1,850	1,420
Northern Idaho	1,420	1,020	1,880	1,960	1,940	1,410

[1]DF = Douglas-fir.
PP = Ponderosa pine.
S-F = Engelmann spruce-subalpine fir.
C-H = Western redcedar-western hemlock.
L = Western larch-grand fir.
LP = Lodgepole pine.

for all cover types. The estimates of volume include material ranging from recently dead sound pieces to highly decayed and deteriorated pieces. Because the field observation of percent rotten included all degrees of decay, some material classed as rotten could be utilized for some purposes, such as fuel. Probably about one-third to one-half of the material classed as rotten could withstand the stresses of skidding and be suitable for fuelwood.

Estimates of volume are more accurate than weight because the planar intersect method used in the inventories provides direct estimates of volume. Weight is calculated assuming wood densities. Volume of large woody material can be calculated from ton-per-acre loadings using the formula:

$$V = \bar{w}\,(25.26\ Rf + 80) \qquad (1)$$

where:

V = volume, ft³/acre
$\bar{w}$ = loading, t/acre
Rf = fraction of weight that is rotten.

Equation (1) was derived using wood densities of 25 and 19 lb/ft³ (0.40 and 0.30 g/cm³) for sound and rotten material, respectively. Volumes in decadent or high-risk stands should be greater than in table 4 as is indicated by the ratios in table 3.

Additional information on volumes, condition, and product potential of downed and standing dead wood is reported by Benson and Schlieter (in preparation)[1]. For mature stands in Montana and Idaho, they determined volumes according to no defect, sound defect, solid rot, and crumbly rot. Crumbly rot (pieces that will not hold together in logging) ranged from about 20 percent in lodgepole pine to 80 percent in larch. Benson and Strong (1977) reported on piece size and product suitability of lodgepole pine.

Volumes (million cubic feet) of large downed woody material occurring in western Montana and northern Idaho were computed using volumes in table 4 and acres of commercial forest land[2]:

Land base	Western Montana	Northern Idaho	Total
National Forest	8.7	6.2	14.9 (422,000 m³)
All lands	12.6	12.8	25.4 (719,000 m³)

The estimates for all lands are based on the assumption that volumes of downed woody materials on private, State, and other Federal lands are comparable to volumes on National Forest land. Data were unavailable to evaluate this assumption. Volumes of large downed woody material and acreages by cover type in western Montana and northern Idaho are presented in appendix VI.

Excess Downed Woody Material

An important question for forest managers to answer is how much downed woody material is desirable to retain on site for purposes such as nutrient cycling, wildlife habitat, and site protection. A balance is desirable between beneficial uses of downed wood in the ecosystem and detrimental influences, such as excessive fire hazard and impediments to animal and human activities. The balance is attained at some optimum quantity of downed woody material that probably varies by forest communities and management circumstances.

Although quantitative evaluation of optimum quantities has received little attention in the literature, reasonable approximations seem possible. Recent evidence by Harvey (in preparation)[3] indicates that 10 to 15 tons/acre (2.2 to 3.4 kg/m²) of downed woody material greater than 6 inches (15 cm) in diameter is desirable to maintain high levels of ectomycorrhizal activity. This amount should not create unreasonable fire hazards; quantities greater than 15 to 20 tons/acre (3.4 to 4.5 kg/m²) would, however, diminish fire protection efficiency.

Assuming 10 tons/acre (950 ft³/acre) is desirable, figure 6 indicates that the larch and spruce-fir cover types contain the greatest quantities of excess downed woody material. Excess quantities were computed by subtracting 950 ft³/acre (66.5 m³/ha) from the large downed woody material volumes in table 4. This analysis suggests that ponderosa pine and Douglas-fir cover types are deficient in downed woody material or contain only slight excesses. Efforts to utilize downed woody biomass should not focus on these types.

In cover types supporting substantial excesses of downed wood, most or all of the quantity desired to remain on site could be rotten material. Since rotten material normally would not be sought as a product, utilization of sound and slightly decayed material should be compatible with need for leaving downed material. This could change in the future — then overutilization will become a problem to forest managers.

[1]Benson, Robert E., and Joyce Schlieter. Woody material in Northern Rocky Mountain forests: volume, characteristics, and changes with harvesting.

[2]Statistics compiled by the Resources Evaluation Unit, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah.

[3]Harvey, A.E., M.F. Jurgensen, and M.J. Larsen. Importance of quantity and type of organic reserves to ectomycorrhizae in forest soils in western Montana.

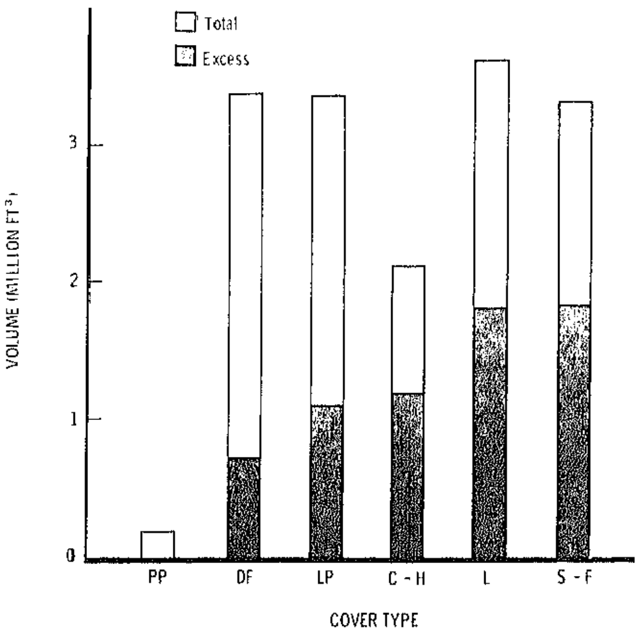

Figure 6.— Total and excess volume of large downed woody material by cover type in western Montana and northern Idaho. Excess volume is material exceeding 950 ft³/acre.

LOADING AND STAND RELATIONSHIPS

Multivariate Analyses

One of the objects of this study was the development of predictive equations for fuel loadings as statistical functions of geographic, physiographic, and environmental factors. Various models were formulated for these relationships using the variables as recorded and with suitable transformations. The down woody loadings were used as response variables both individually and in combination as small fuel load, large fuel load, and total fuel load (small and large). Stand age, slope, aspect, and elevation were used as the independent variables in the model formulation. Experience has shown that some variables should be transformed before inclusion in the models. For example, aspect was recorded as a coded observation bearing little relation to its influence on environmental conditions. A sine and cosine transformation of aspect was used to better typify this influence.

Various scatter plots and regression screens were carried out using standard plot routines and the REX Program (Grosenbaugh 1967), both available on the Lawrence Berkeley Laboratory (LBL) CDC 7600 computer. Examination of the output showed other transformations that might be appropriate, such as using the natural logarithm of down woody fuel loadings as the response variables. The chosen models were fit by a stepwise multiple linear regression program at LBL.

Very little of the observed variation in loading was explainable by any of the factors included in the models. In the event that either habitat type or cover type was masking the assumed relationships, the models were fit within these strata. Again, little of the variation in loading was explainable.

Table 5 shows typical results from the regression analysis. Regression coefficients are shown for significant independent variables. The partial F-value shows the relative contribution of that variable (Draper and Smith 1966). The R^2 indicates the percent variation explainable by the equation for the included variables. As shown in table 5, little predictive ability was available in these fits. We concluded that either the factors examined had little relation to the variation in down woody fuel loading, or other factors were masking these relationships.

Loading Versus Stand Age

A commonly espoused notion about fuel accumulation is that fuels accumulate over time attaining hazardous fire potentials as stands reach old age. We expected to observe this in analysis of the data; however, support for this notion was not found. We failed to observe any consistent relationship, pattern, or periodicity to demonstrate that downed dead woody fuel loading increases with stand age.

Analysis of the relationship between stand age and loading is complicated by ambiguities in determining stand age. Ideally, stand age would reflect time since last major disturbance by fire as well as time since origin of stand. However, this appears to happen for only a minority of stands in the Northern Rocky Mountains. All-aged stands of mixed species, which appear to represent most stands in the Northern Region, present the most uncertainties in determining age and in interpreting what it means in relation to fuel accumulation.

In analysis of the Resources Evalution data, both Resources Evaluation stand age (based on the oldest trees of species defining the type) and first component age (based on age of the species having the greatest basal area per acre) produced similar lack of correlations. Age had not been determined for the Stand Examination data; so we developed a stand age algorithm for computer processing of individual plot data. This algorithm, which determines average age of the oldest trees for species defining a cover type, might be useful for other purposes. It operated as follows:

Step 1. Determine minimum age of trees qualifying for calculation of stand age. Using the maximum age of inventoried trees up to 350 years as a basis, the minimum qualifying age is:

$$\text{Min. age} = (\text{Max. age})\ [1-0.337 + 0.000908(\text{Max. age}) - 0.00000111(\text{Max. age})^2] \qquad (2)$$

When the maximum age is greater than 350 years:

$$\text{Min. age} = 0.85\ \text{Max. age} \qquad (3)$$

These functions were established so that minimum age varied from approximately 0.70 to 0.85 of the maximum age.

Step 2. To prevent determination of stand age based on a very old, atypical tree, decide whether the number of trees exceeding the minimum age is an adequate sample. If the sample is inadequate, discard the oldest tree and repeat Step 1. To evaluate adequacy of sample, we arbitrarily required the following number of qualifying trees:

Total number of trees having age observations	Required number of trees exceeding minimum age
0-9	1
10-40	2
over 40	3

Table 5.—Statistics from regression analysis of total downed woody loading[1] on the independent variables slope, stand age, aspect, and elevation

Independent variable	All Groups		Habitat Group 1		Habitat Group 2		Habitat Group 3	
	Coefficient	Partial F[2]	Coefficient	Partial F	Coefficient	Partial F	Coefficient	Partial F
Constant	24.5		-0.60		10.6		22.0	
Slope	-1.6	76.8		0.1	-.34	14.4		2.5
Age	0.012	9.2	.34	17.7	.51	108	-.27	12.0
Cos(aspect)	2.8	34.2		3.7	.77	5.6	2.1	22.3
Elevation		2.2	.10	4.5		.5	-.17	18.9
Sin(aspect)		1.9	1.4	6.8		.2		7.1
	R^2 = 0.05		R^2 = 0.06		R^2 = 0.05		R^2 = 0.09	
	Habitat Group 4		**Habitat Group 5**		**Habitat Group 6**		**Habitat Group 7**	
	Coefficient	Partial F	Coefficient	Partial F	Coefficient	Partial F	Coefficient	Partial F
Constant	39.0		15.9		18.0		10.9	
Slope	-3.0	239	-1.7	184	-1.7	102	-4.1	121
Age		1.9	.69	168	.65	81		2.4
Cos(aspect)	-2.6	38.3	.87	7.8	5.1	140	-4.7	32
Elevation	-.15	26.6	.15	31.3	.25	25	.57	46
Sin(aspect)	-6.1	224		.4	-2.1	65	5.2	43
	R^2 = 0.15		R^2 = 0.08		R^2 = 0.09		R^2 = 0.13	

[1]Total downed woody loading was transformed into natural logarithms for individual habitat type groups, but was untransformed for All Groups.
[2]Statistical significance of the Partial F for variable selection is based on F (1.00, 0.95) = 3.84.

Step 3. Calculate average age of qualifying trees exceeding minimum age.

Scattergrams between stand age and small woody biomass, large woody biomass, and duff depth were examined for age partitioned into 1-, 20-, and 50-year classes. The data were stratified by individual Forests, Eastside and Westside Forests, and the entire Region. Results were primarily a wide scatter of points as shown in figure 7. Interestingly, all age classes exhibited high within-class variability; loadings ranged from zero to some high value. Usually, the extreme loadings were similar among age classes. Sometimes a particular cover type in a particular Forest showed periodicity between loading and stand age, but a consistent pattern was not evident.

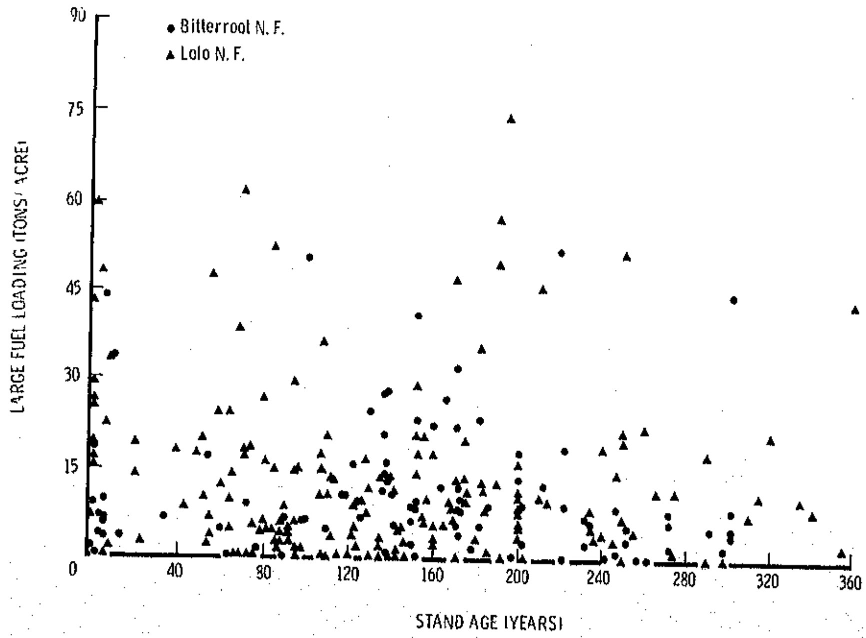

Figure 7. — Scattergrams between average stand large fuel loadings and stand age for all cover types in Region 1, based on Forest Survey data.

The large variability within age classes may have masked some relationships. Hoping to circumvent this problem, the top 20th percentile loadings of each age class were plotted for individual Forests and the entire Region. As before, some periodicity between loading and stand age was suggested, but consistent trends did not emerge.

The failure to find a substantive relationship between loading and stand age is probably due to two factors. One, mortality and downfall of trees, occurs at all stand ages, not just in old stands. Two, high variability among stands obscures and weakens relationships that might exist.

Few studies aimed at determining the relationship between downed woody fuel loading and stand age have been conducted. Available evidence, however, indicates a lack of consistent pattern in buildup and decline of fuel loading with stand age. In stands on dry-to-moist sites in the Selway-Bitterroot Wilderness of Idaho, Habeck, (1976) found that for most cover types, loadings of large downed woody material were greater in mature stands than in developing stands. In stands of mixed species in the Paysayten Wilderness, Washington, Fahnestock (1976) found that loadings of large material ranged from low to high in developing stands. Loadings were least in mature stands, then increased over the period that stands were 200 to 400 years of age.

Probably more data on fuel succession exist for lodgepole pine than any other type and it exemplifies the lack of consistent patterns. In figure 8, median large fuel loadings were normalized using the maximum loading for each of three studies. Loadings from northern Idaho and western Montana increased continuously with age. In Glacier National Park (Jeske and Bevins 1979), loadings decreased until stands were about 100 years old, then they increased. In the Selway-Bitterroot Wilderness, Idaho,[4] the loading trend was the reverse of that in Glacier National Park. In lodgepole pine on the Colorado Front Range, Alexander (1979) found a wide scatter in loading and stand age.

Because considerable data existed for the subalpine fir cover type, they were sorted by groups of two adjacent National Forests and loading patterns examined. The inconsistency in successional patterns is illustrated by the three loading trends observed for subalpine fir (fig. 9). The Flathead-Kootenai and Colville-Idaho Panhandle National Forests displayed similar trends. Loadings were high during the juvenile period, dropped during the immature and early maturity periods, and rose to a relatively high level maintained during the late maturity and overmature periods. This pattern is probably the most commonly encountered in forest types that begin after a high-intensity fire or insect epidemic causing high mortality.

High loadings during the juvenile period are caused by downfall of dead trees from the previous stand. Considerable time may be required for trees from the previous stand to decay and settle into the forest floor. In the event of another fire occurring during the juvenile period and consuming most of the downfall, the next stand will have much smaller downed fuel loadings during the juvenile period.

The commonly held notion that fuel quantities accumulate with age is, in many cases, untrue. Fuel succession is a complex process of many interacting factors. The generalization that fuels accumulate with time is an oversimplification. Two consistencies in fuel succession proposed for lodgepole pine (Brown 1975) seem to hold for all cover types: (1) fuel quantities become predictably high as stands become overmature, and (2) fuel quantities cannot be predicted from age alone in young, immature or mature stands. These consistencies are probably invalid for intensively managed stands where downed fuel quantities are controlled by cutting and removal activities.

In some vegetation communities, growth of understory vegetation such as young conifers can add substantially to fuel loadings and fire behavior potential. Fuel succession is more complicated when both living and dead fuels are involved because living fuels may increase while dead fuels decrease and conversely. When both dead and living fuels accumulate together, fire behavior potential can become excessively high. This probably occurs most frequently in overmature stands. Fuel characteristics are constantly changing to either increase or reduce flammability. Generalizations about fuel accumulation should be regarded with circumspection.

[4]Bevins, Collin D. 1977. Natural fuels accumulation in lodgepole pine. Unpub. rep. on file with "Systems for Environmental Management," Missoula, Mont.

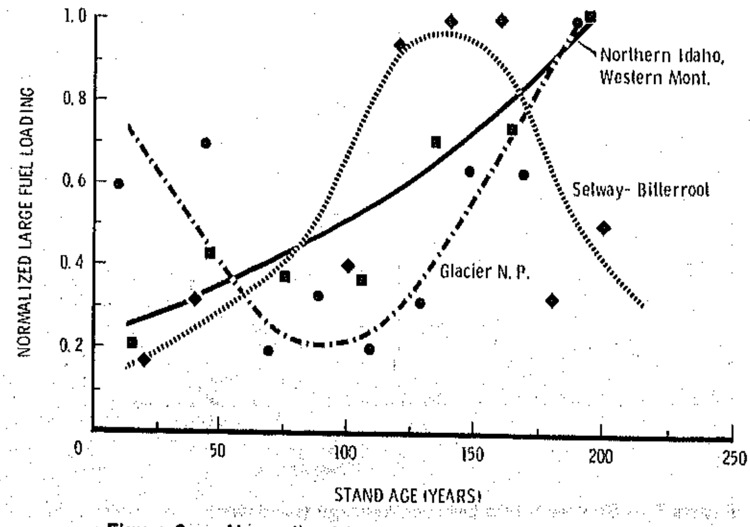

Figure 8. — Normalized loading of large downed woody fuel in lodgepole pine stands of varying age from three studies.

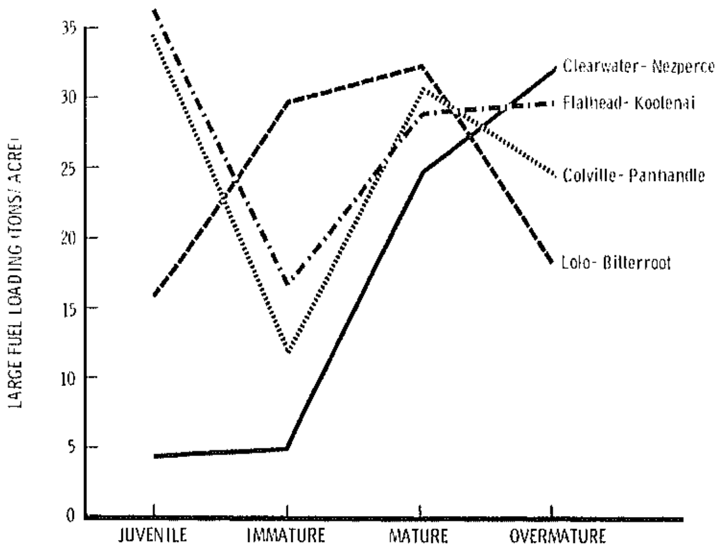

Figure 9. — Loading of large downed woody material in the subalpine fir cover type related to stand chronology. Juvenile encompasses stand ages of 0 to 50 years; immature, 51 to 100 years; mature, 101 to 150 years; and overmature, greater than 150 years.

Loading Versus Productivity

Loading generally increases with productivity as is shown in figures 10 and 11. The increasing trends probably exist because more productive sites grow more woody biomass for accumulation as downed woody fuel.

Unfortunately, the scatter of points in figures 10 and 11 indicates that accuracy in predicting loading from productivity would be poor. The scatter of points is probably due partly to fortuitous mortality events and random variation in the sample. Decay rates of wood and fire frequency may also explain some of the scatter. For example, loadings of some cold, dry site habitat types having relatively low productivities are similar to warm, moist site habitat types having relatively high productivities. Perhaps the net accumulation of fuel from the processes of accretion and decay is similar on the contrasting sites because lower decay rates on cold, dry sites offset the greater productivities on warmer, moist sites.

Historical fire frequency may account for differences in loadings among some habitat types of similar productivity. For example, *Abies lasiocarpa/Oplopanax horridum* and *Thuja plicata/Oplopanax horridum* habitat types have very high loadings (fig. 10). These moist sites are infrequently visited by fire leaving decay as the only process for reducing fallen trees to nonwoody compounds. Other habitat types of similar productivities, such as *Abies grandis/Clintonia uniflora* and *Thuja/Clintonia,* have less downed woody fuel perhaps because more frequently repeated fires have helped eliminate accumulated biomass. If effective fire control of the past 40 years is continued into the future, eventually fire frequency will cease to be a factor in causing different fuel accumulations.

Loading Versus Elevation and Aspect

We analyzed large fuel loadings for data stratified by aspect within elevation zones within cover types. Aspects were grouped into two categories, warm (SE, S, SW, W) and cool (NW, N, NE, E). Elevation was grouped into 1,000-ft zones. This analysis was repeated for groups of two National Forests and by Eastside and Westside National Forests.

For the two-Forest groups, loadings differed among some elevations and aspects; the differences, however, were inconsistent among cover types and Forests. The inconsistency together with limited data precluded drawing conclusions about elevation and aspect on a two-Forest basis. For the Westside and Eastside Forests, the data was substantial. Results showed that differences in loadings between elevations and between aspects were mostly small and lacked an explainable pattern (table 6). Thus, prediction of loadings from aspect and elevation seemed unwarranted. A few interesting trends were suggested, however. For example, on Eastside Forests, loadings of Douglas-fir were less below 6,000 ft (1 829 m) than above this elevation, whereas on Westside Forests, loadings of Douglas-fir fell off above 6,000 ft (fig. 12). Loadings in Westside Douglas-fir above 6,000 ft may fall off because at this elevation it is a marginal species with restricted productivity. Loadings of lodgepole pine were greater on north than south aspects, but real differences in loadings due to elevation were not apparent. For the larch-grand fir cover type, loading showed an increasing trend with elevation. For cedar-hemlock, loading was maximum at 4,000 to 5,000 ft (1 219 to 1 524 m) with smaller loadings above and below that elevation (table 6).

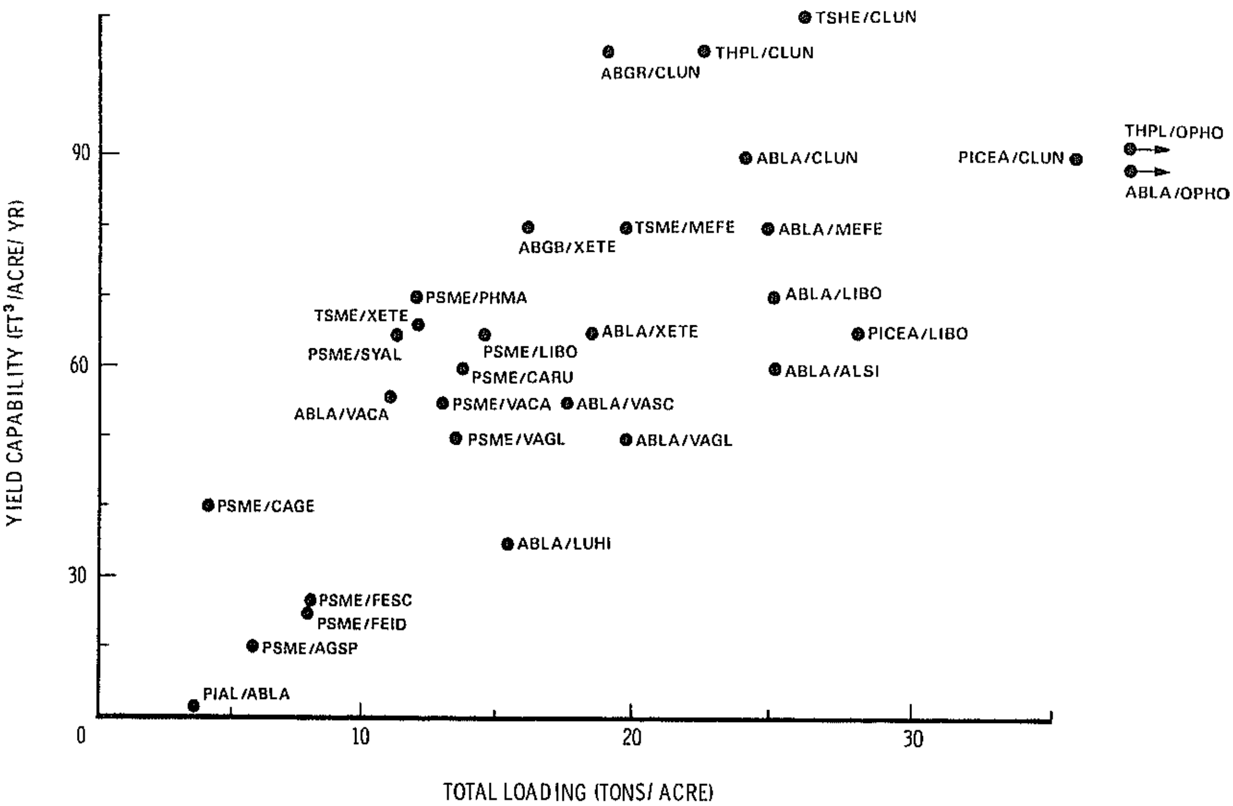

Figure 10.—Ordination of habitat types by yield capability and total downed woody fuel loading for Westside Forests. Yield capabilities are from Pfister and others (1977). Plotted habitat types are represented by at least 5 stands or 35 sample points.

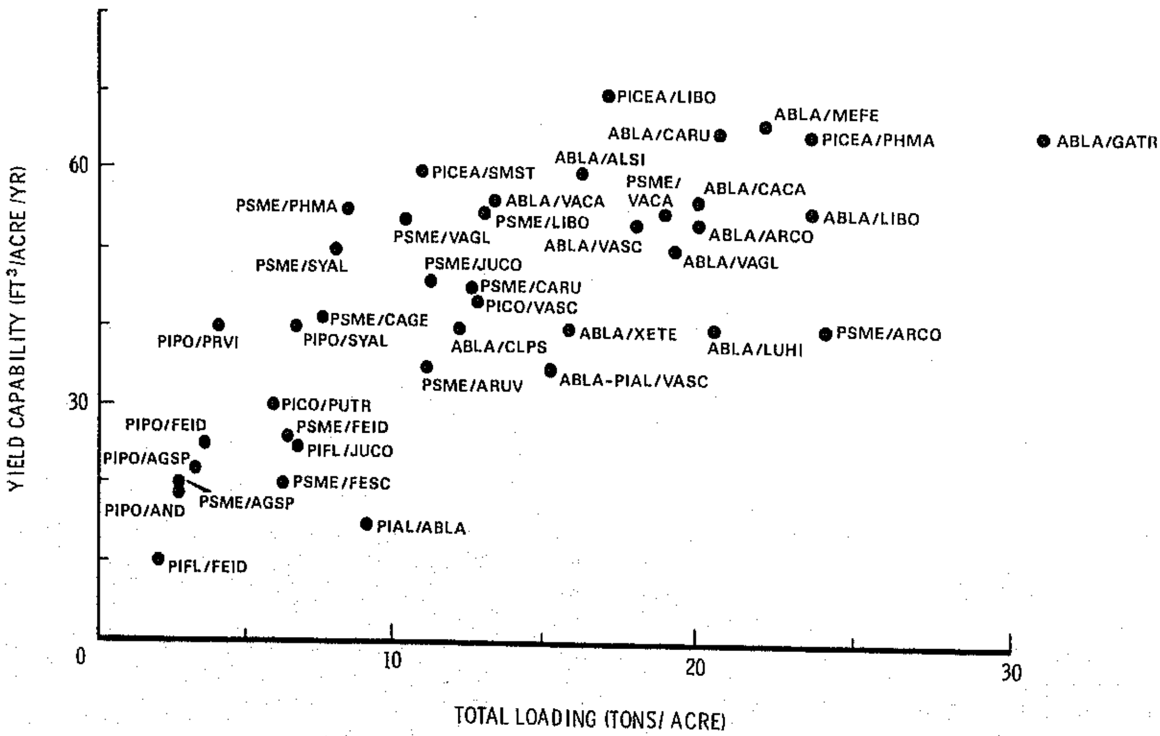

Figure 11.—Ordination of habitat types by yield capability and total downed woody fuel loading for Eastside Forests. Yield capabilities are from Pfister and others (1977). Plotted habitat types are represented by at least five stands or 35 sample points.

Table 6.—Weighted mean loadings of large downed woody material for northerly and southerly aspects within 1,000-ft elevation bands b cover type. Number of sample stands is shown in parentheses

Cover type[1]	Elevation (feet) and aspect (north or south)									
	3,000-3,900		4,000-4,900		5,000-5,900		6,000-6,900		7,000-7,900	
	N	S	N	S	N	S	N	S	N	S
	Tons/acre									
	Westside National Forests									
DF	11.2	12.1	15.3	9.2	13.5	12.7	7.6	7.4		
	(138)	(305)	(178)	(165)	(150)	(157)	(63)	(58)		
LP	16.6	11.4	18.2	10.4	14.7	12.4	13.3	11.9		
	(20)	(47)	(202)	(94)	(122)	(145)	(71)	(44)		
S-F			29.2	20.9	23.9	34.4	20.5	21.7		
			(56)	(43)	(220)	(101)	(163)	(50)		
L	15.0	11.8	15.4	16.5	22.5	18.2				
	(164)	(212)	(224)	(127)	(92)	(44)				
C-H	29.5	21.8	32.4	34.9	20.4	15.8				
	(39)	(78)	(93)	(41)	(31)	(32)				
	Eastside National Forests									
DF					7.3	6.5	9.3	9.0	13.4	10.0
					(64)	(64)	(114)	(150)	(70)	(39)
LP					8.9	9.1	13.2	10.7	14.2	12.4
					(27)	(15)	(138)	(99)	(177)	(114)

[1]DF = Douglas-fir.
LP = Lodgepole pine.
S-F = Engelmann spruce-subalpine fir.
L = Western larch-grand fir.
C-H = Western redcedar-western hemlock.

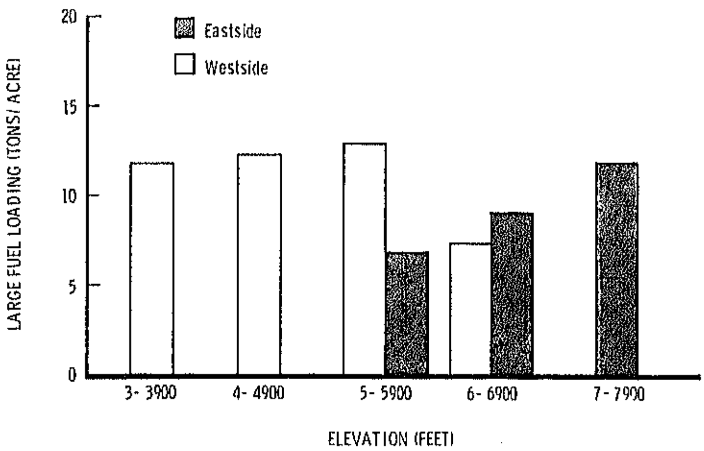

Figure 12. — Large fuel loadings averaged for 1,000-ft elevation zones in the Douglas-fir cover type on Eastside and Westside National Forests.

Accumulation of downed woody material might be expected to relate to elevation and aspect because of differences in rates of decay and productivity. However, because many factors, such as cover type and stand history, also account for accumulations of downed woody material, isolating the influence of elevation and aspect was difficult. Extensive data were required to evaluate influences of elevation and aspect on fuel loading. Where data permitted a reasonably confident analysis, the influences of elevation and aspect on loading were rather small. Factors accounting for the influences remain in question, but probably relate to causes of tree mortality.

Duff depth was significantly greater on cool than on warm aspects in ponderosa pine and to a lesser extent in cedar-hemlock (table 7). Duff depth, however, did not vary significantly between aspects for other cover types as was observed by Alexander (1979) for lodgepole pine in Colorado. The difference in duff depths between aspects in ponderosa pine may be due mostly to lower stocking and litter fall on southerly exposures. Aspect was suspected of influencing duff depth because decay was expected to progress more slowly on cool sites. The data suggest, but do not confirm it.

Photo Interpretation of Loading

The possibility of using aerial photography to determine fuel loadings was investigated using the Northern Region Photo Interpretation Classification (Stage and Alley 1972). Eight photo interpretation groups were formed from the Region's larger PI Classification. Region 1's codes for these groups are shown in appendix VII.

Group means weighted by number of plots and a Scheffe's multiple comparison test at the 90 percent confidence level indicate that little discrimination among photo interpretation (PI) classes is warranted (table 8). On the Westside, the following three PI class groups appear justified for interpreting loadings based on the similarity of means and tests of differences:

PI class	Loadings	
	Large fuel	Small fuel
	Tons/acre	
Stands poorly stocked	9.1	2.4
Stands medium and well stocked	16.4	3.1
Cutover stands	22.8	3.9

On the Eastside, analysis suggests that PI class is of no value for estimating loading. The bulk of the data represented medium- and well-stocked pole and sawtimber stands, which for large fuels averaged about 12 tons/acre (2.7 kg/m²). Loadings of the other groups displayed an ambiguous pattern.

Loadings of the PI groups were not normally distributed. Thus, the results of Scheffe's tests are inexact, but still of interest with cautious interpretation. Because of highly variable loadings, PI class can be used appropriately only for broad coverage groups such as tabulated for the Westside.

Table 7.—Average duff depths on warm and cool aspects in Westside National Forests

Aspect	Cover type[1]					
	LP	S-F	L	DF	C-H	PP
	Inches					
Warm	1.13	1.42	1.15	0.86	1.36	0.51
Cool	1.13	1.44	1.23	.94	1.57	.97
Difference	0	.02	.08	.08	.21	.46

LP = Lodgepole pine.
S-F = Engelmann spruce-subalpine fir.
L = Western larch-grand fir.
DF = Douglas-fir.
C-H = Western redcedar-western hemlock.
PP = Ponderosa pine.

Table 8.—Mean loadings for photo interpretation groups on Westside and Eastside National Forests. The vertical lines connect groups whose means are nonsignificantly different

Group number[1]	PI class	Number of plots	Large material	Small material
			Tons/acre	*Tons/acre*
	Westside			
6	Under 40, poor	354	8.2	2.4
3	Over 40, poor	559	9.7	2.4
2	Over 40, medium and well, pole	6,718	15.0	3.1
1	Over 40, medium and well, saw	4,094	17.3	3.1
5	Under 40, medium and well	653	17.7	3.2
4	Over 40, two-storied	4,378	17.7	3.0
8	Cutover, poor	1,535	20.9	3.7
7	Cutover, medium and well	1,748	24.4	4.1
	Eastside			
3	Over 40, poor	435	5.8	1.2
1	Over 40, medium and well, saw	4,745	11.6	2.3
2	Over 40, medium and well, pole	1,676	12.9	2.4
7	Cutover, medium and well	147	13.6	3.1
5	Under 40, medium and well	366	13.6	2.1
8	Cutover, poor	232	17.1	3.4
6	Under 40, poor	36	18.6	3.7
4	Over 40, two-storied	244	18.7	3.0

[1] 1 = Limber pine (*Pinus flexilis*); ponderosa pine, and Douglas-fir/bunch grass types.
2 = Dry site Douglas-fir and moist site ponderosa pine.
3 = Moist site Douglas-fir.
4 = Cool sites dominated by lodgepole pine; dry, lower elevation subalpine fir.
5 = Moist site, lower elevation subalpine fir.
6 = Cold, moist site upper elevation subalpine fir.
7 = Warm, moist sites; mostly cedar-hemlock.

FIRE MANAGEMENT APPLICATIONS

Estimates of fuel loadings and fire behavior can help in planning at all administrative levels and in conducting presuppression, suppression, and prescribed fire activities. Besides downed woody material, fuels such as litter, grasses, forbs, and shrubs are often essential in appraising fire potential. However, knowledge of downed woody material alone can be useful because within given forest communities, it can vary substantially while loadings of herbaceous vegetation and litter remain more uniform. Thus, assuming topography and weather are constant, differences in fire behavior among stands from the same forest community type are most likely due to differences in loading of downed woody material especially on mesic and wet sites.

Some specific applications might include:

1. Decisions can be made as to whether or not fuel inventory is necessary on areas planned for harvesting. If large fuel loadings are expected from harvesting, inventory of existing fuels may be desirable; but, if small loadings are expected, inventory is likely to be unnecessary. Slash fuel hazard can be appraised using procedures described by Puckett and others (1979). These procedures require estimates of fuel loadings existing before cutting. Although loading estimates summarized here are less accurate than provided by inventory, they might be used where inventory is impractical.

2. Loading summaries could be used to help select proper fuel models for operating the National Fire-Danger Rating System (Deeming and others 1977) and estimating wildfire behavior using nomographs (Albini 1976). In both cases, users must sometimes select between fuel models for forests having only a nominal loading of downed woody fuel and forests having a heavy accumulation of downed fuel. Depending upon the accuracy required in applying fire-danger ratings or fire behavior estimates, average loadings by broadly defined vegetation types can help in selecting between fuel models having nominal and heavy loadings.

3. Loading summaries are appropriate for fuel and fire management planning requiring low resolution fuel information. Loading information alone can be useful for appraising problems of fuels greater than 3 inches in diameter. Fire behavior potentials of large fuels are inadequately appraised when only rate of fire spread and intensity are considered. Although large fuels contribute to flame front advance, they probably present more difficulties to land managers because of their prolonged burnout time. This can lead to undesirable fire effects. Fire suppression in large fuels is arduous and expensive. Large fires easily occur in accumulations of large fuels because sustained burning and smoldering create prolonged ignition sources that high winds can readily fan into fast moving fires. Although interpretation of large fuel problems requires considerable judgment, knowledge of loadings provides an objective foundation on which to evaluate fire behavior potentials.

SUMMARY AND CONCLUSIONS

Weights and volumes of downed woody biomass and fuel in diameter classes of one-fourth to 1 inch (0.6 to 2.5 cm), 1 to 3 inches (2.5 to 7.6 cm), and greater than 3 inches (7.6 cm) and of forest floor duff depths were summarized from extensive inventories in northern Idaho and Montana. Quantities of downed woody material varied more among cover types than among habitat types because cover types reflect the tree species comprising most of the downed woody material.

Total, downed woody biomass east of the Continental Divide ranged from 5 tons/acre (11.2 t/ha) in the ponderosa pine cover type to 23 tons/acre (51.6 t/ha) in the spruce-fir. West of the Divide, loadings ranged from 13 tons/acre (29.2 t/ha) in ponderosa pine to 33 tons/acre (74.0 t/ha) in cedar-hemlock. Duff depths for cover types ranged from 0.5 to 1.5 inches (1.3 to 3.8 cm). Westside Forests displayed greater loadings and larger piece diameters than Eastside Forests probably because productivities and tree sizes average greater on the Westside.

High-risk stands contained up to three times as much as the average downed woody biomass on individual National Forests. Assuming that 10 tons/acre (22.4 t/ha) of downed woody biomass greater than 3 inches (7.6 cm) in diameter should be retained on site, the greatest excess quantities per acre occurred in the cedar-hemlock and spruce-fir cover types. The only cover type not showing an excess was ponderosa pine.

The data were highly variable and skewed strongly to the right, indicating that downed woody material tends to occur in scattered concentrations rather than in uniform distributions. Correlations between loadings of different size classes were poor. Thus, loadings of one size class cannot be predicted with reasonable precision from loadings of another size class.

On Westside Forests, photo interpretation classes representing (1) stands poorly stocked, (2) stands medium- and well-stocked, and (3) cutover areas discriminated significantly different large fuel loadings. On Eastside Forests, PI classes were unable to distinguish significantly different loadings.

Cover type and habitat type group averages provided the most meaningful estimation of loadings. Loadings generally increased with productivity, presumably because more productive sites grow more biomass that eventually falls to the ground in the absence of utilization. Regression analysis failed to produce reliable relationships between the dependent variables of duff depth and downed woody material and the independent variables of stand age, slope, aspect, and elevation ($R^2 = 0.05$ to 0.15).

The lack of substantive relationships between downed biomass loadings and stand age is probably due to several factors including high variability in loadings among stands. More importantly, tree mortality and downfall can occur at all stand ages. The relationship between biomass accumulations and stand age is ambiguous because the origin of stands was often unclear. Most stands contained a wide range of tree ages.

Biomass accumulates with time, but the generalization that fuels accumulate with time is replete with exceptions. This study and review of others indicate that downed woody fuel quantities tend to become predictably high as stands become overmature, but unpredictable from age alone in young immature and mature stands. Generalizations about fuel accumulation should be interpreted and applied cautiously.

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APPENDIX I

Forest Inventory Fuel Summaries by National Forest

Loadings of downed woody material and duff depths are summarized by National Forest and cover type in table 9 and by habitat type groups in table 10. Cover types known to occur on a National Forest, but not shown in the tables were represented by too little data to warrant analysis. The western white pine cover type was almost included, but it occurred with only marginally acceptable data on two National Forests. To qualify for summary in the tables, at least 10 stands or 75 sample points were required. Number of sample points is shown only with the 0.25- to 1-inch (0.6- to 2.5-cm) category; it is the same for all other categories within a National Forest.

Duff depth shown in the tables can be a useful expression of duff quantity. However, if duff loading is desired for some purposes, it can be computed by knowing bulk density. Duff bulk density is known to vary from 4.7 lb/ft^3 (0.075 g/cm^3) in ponderosa pine stands (Brown 1970) to 11.2 lb/ft^3 (0.18 g/cm^3) in western hemlock and Douglas-fir stands (Mader 1953). In lodgepole pine stands, it averaged 8.7 lb/ft^3 (0.14 g/cm^3) (Brown 1974b). Assuming a bulk density of 8 lb/ft^3 (0.13 g/cm^3), loading in tons per acre can be calculated as 14.5 times duff depth in inches. Assuming a bulk density of 5.5 lb/ft^3 (0.088 g/cm^3), suitable for ponderosa pine, loading in tons per acre can be calculated as 10 times duff depth in inches. Unless measured bulk densities are available, these expressions provide rough approximations of duff loadings for most forest types.

Table 9. — Loadings of downed woody material and depths of forest floor duff by National Forest and cover type from Forest Survey data

Fuel category	Cover type	Mean	Standard deviation	First quartile	Median	Third quartile	Number points
		Tons/acre					
		Bitterroot National Forest					
	PP	0.4	0.8	0	0	0.5	218
	DF	.5	.8	0	0	.8	1,056
¼ to 1 inch	LP	.4	.6	0	0	.5	203
	S-F	.6	1.0	0	0	.9	156
	All	.5	.8	0	0	.8	1,633
	PP	1.0	2.7	0	0	0	
	DF	1.2	2.8	0	0	2.1	
1 to 3 inch	LP	1.1	2.2	0	0	2.1	
	S-F	1.3	2.4	0	0	2.1	
	All	1.1	2.7	0	0	2.1	
	PP	5.3	14.0	0	0	1.5	
	DF	9.2	18.7	0	0	10.6	
Large	LP	12.2	19.8	0	0	17.2	
	S-F	16.1	24.9	0	5.3	22.9	
	All	9.7	19.1	0	0	11.0	
	PP	7	15	0	0	4	
	DF	11	20	0	1	14	
Total woody material	LP	14	21	0	2	19	
	S-F	18	27	0	8	28	
	All	11	20	0	.8	14.6	
		Inches					
	PP	0.4	1.0	0	0	0.2	
	DF	.5	.8	0	0	.6	
Duff depth	LP	.5	.9	0	0	.6	
	S-F	.8	1.7	0	0	.9	
	All	.5	1.0	0	0	.6	
		Tons/Acre					
		Clearwater National Forest					
	DF	1.4	1.2	0.6	1.0	1.9	520
	LP	1.0	1.1	0	.6	1.4	458
¼ to 1 inch	L	1.5	1.3	.5	1.2	2.2	517
	S-F	.9	1.1	0	.6	1.3	453
	C-H	1.4	1.3	.6	1.0	2.0	501
	All	1.2	1.2	.3	.9	1.7	2,449
	DF	3.3	5.1	0	2.2	4.9	
	LP	1.4	3.6	0	0	2.2	
1 to 3 inch	L	3.1	5.1	0	0	4.6	
	S-F	1.9	3.7	0	0	2.3	
	C-H	3.2	5.4	0	2.1	4.8	
	All	2.6	4.8	0	0	2.7	
	DF	15.9	29.3	0	0	19.8	
	LP	7.3	18.8	0	0	4.4	
Large	L	19.4	32.6	0	3.1	26.7	
	S-F	14.6	35.1	0	0	16.5	
	C-H	24.3	31.9	0	12.3	34.4	
	All	16.5	30.6	0	1.6	21.5	
	DF	21	30	2	8	26	
	LP	10	20	0	2	10	
Total woody material	L	24	34	2	10	33	
	S-F	17	36	1	5	21	
	C-H	29	33	5	19	40	
	All	20	32	1	7	27	
		Inches					
	DF	0.9	1.3	0	0.3	1.1	
	LP	.5	1.0	0	.1	.6	
Duff depth	L	1.1	1.4	0	.6	1.6	
	S-F	.9	1.5	0	.3	1.2	
	C-H	1.3	1.7	.2	.6	1.7	
	All	.9	1.4	0	.3	1.3	

(Con.)

Table 9. — (Con.)

Fuel category	Cover type	Mean	Standard deviation	First quartile	Median	Third quartile	Number points
				Tons/acre			
			Colville National Forest				
	PP	1.1	1.2	0.2	0.6	1.4	196
	DF	1.3	1.3	.3	.8	1.9	528
¼ to 1 inch	LP	1.4	1.2	.5	1.1	2.1	310
	L	1.5	1.3	.5	1.1	2.2	1,838
	S-F	1.3	1.2	.3	.9	1.8	245
	C-H	1.6	1.2	.6	1.2	2.3	249
	All	1.4	1.3	.3	1.1	2.2	3,366
	PP	2.7	5.6	0	0	3.4	
	DF	2.5	4.0	0	0	4.3	
1 to 3 inch	LP	3.1	5.1	0	2.1	4.4	
	L	2.8	4.2	0	2.1	4.4	
	S-F	3.2	4.7	0	2.2	4.5	
	C-H	3.6	4.6	0	2.2	4.6	
	All	2.8	4.5	0	2.1	4.4	
	PP	22.8	34.2	0	5.3	34.2	
	DF	15.1	27.9	0	3.1	18.1	
Large	LP	19.1	25.9	0	8.0	27.2	
	L	17.0	26.0	0	6.4	22.4	
	S-F	38.4	41.3	6.7	28.8	54.3	
	C-H	41.1	53.1	4.8	24.6	53.6	
	All	20.6	32.0	0	7.9	28.7	
	PP	27	36	1	11	39	
	DF	19	29	1	8	25	
Total woody material	LP	24	15	4	14	35	
	L	21	27	3	12	29	
	S-F	43	42	12	34	59	
	C-H	46	54	11	31	62	
	All	25	33	4	13	34	
				Inches			
	PP	0.6	0.8	0	0.3	0.8	
	DF	.7	1.0	0	.3	1.0	
Duff depth	LP	1.0	1.1	.3	.8	1.4	
	L	1.1	1.2	.2	.8	1.5	
	S-F	1.5	1.6	.3	1.1	2.0	
	C-H	1.8	1.8	.5	1.3	2.8	
	All	1.1	1.3	.2	.7	1.5	
				Tons/acre			
			Deerlodge National Forest				
	DF	0.8	0.9	0	0.5	1.1	981
	LP	.7	.8	0	.5	.8	1,347
¼ to 1 inch	S-F	.8	1.0	0	.5	1.1	279
	All	.7	.9	0	.5	1.1	2,607
	DF	1.7	3.1	0	0	2.2	
	LP	1.6	2.7	0	0	2.2	
1 to 3 inch	S-F	1.7	3.1	0	0	2.2	
	All	1.7	2.9	0	0	2.2	
	DF	10.6	18.9	0	2.2	13.9	
	LP	15.8	27.8	0	7.5	21.9	
Large	S-F	20.4	25.2	0	11.0	30.6	
	All	14.4	24.7	0	5.6	19.9	
	DF	13	20	1	6	18	
	LP	18	28	2	10	25	
Total woody material	S-F	23	26	3	13	35	
	All	17	25	1	8	23	
				Inches			
	DF	1.1	1.1	0.3	.8	1.6	
	LP	1.3	1.3	.3	1.0	2.0	
Duff depth	S-F	1.5	1.6	.4	1.1	2.2	
	All	1.3	1.3	.3	1.0	1.8	

(Con.)

Table 9. — (Con.)

Fuel category	Cover type	Mean	Standard deviation	First quartile	Median	Third quartile	Number points
		Tons/acre					
		Flathead National Forest					
	DF	1.0	1.0	0.3	0.8	1.4	668
	LP	1.0	1.1	.3	.7	1.4	625
¼ to 1 inch	L	.9	.9	.3	.6	1.3	469
	S-F	1.1	1.1	.3	.8	1.6	690
	All	1.0	1.1	.3	.8	1.4	2,452
	DF	1.8	3.4	0	0	2.3	
	LP	2.6	4.3	0	0	2.5	
1 to inch	L	1.8	2.9	0	0	2.2	
	S-F	1.7	3.1	0	0	2.2	
	All	2.0	3.5	0	0	2.3	
	DF	17.0	26.6	0	6.4	23.1	
	LP	18.7	25.2	0	9.0	26.8	
Large	L	18.1	25.9	0	8.4	25.7	
	S-F	28.6	39.7	2.7	16.7	41.8	
	All	20.9	30.8	0	10.0	29.3	
	DF	20	28	2	9	27	
	LP	22	26	3	13	33	
Total woody material	L	21	26	3	11	28	
	S-F	31	40	4	20	44	
	All	24	32	3	13	34	
		Inches					
	DF	1.3	1.5	0.3	0.9	1.8	
	LP	1.3	1.3	.4	1.0	1.8	
Duff depth	L	1.5	1.5	.5	1.1	1.9	
	S-F	2.0	1.9	.6	1.6	2.9	
	All	1.5	1.6	.4	1.1	2.1	
		Tons/acre					
		Gallatin National Forest					
	DF	0.9	1.0	0.3	0.7	1.4	533
	LP	.9	.9	.3	.6	1.1	624
¼ to 1 inch	S-F	.9	1.0	0	.6	1.4	301
	All	.9	1.0	.3	.6	1.2	1,458
	DF	1.8	4.3	0	0	2.2	
	LP	1.9	3.3	0	0	2.2	
1 to 3 inch	S-F	1.7	2.7	0	0	2.2	
	All	1.8	3.6	0	0	2.2	
	DF	10.2	23.1	0	1.2	11.5	
	LP	18.1	35.7	0	6.4	24.7	
Large	S-F	19.6	30.2	0	9.2	24.7	
	All	15.5	30.7	0	4.4	19.8	
	DF	13	26	1	4	15	
	LP	21	37	2	9	29	
Total woody material	S-F	22	31	1	13	29	
	All	18	32	1	7	24	
		Inches					
	DF	1.1	1.3	0.3	0.8	1.6	
	LP	1.1	1.1	.3	.7	1.5	
Duff depth	S-F	1.2	1.6	.2	.7	1.8	
	All	1.1	1.3	.2	.7	1.6	

(Con.)

Table 9. — (Con.)

Fuel category	Cover type	Mean	Standard deviation	First quartile	Median	Third quartile	Number points
		Tons/acre					
		Helena National Forest					
	PP	0.5	0.7	0	0	0.6	184
	DF	.8	1.0	0	.3	1.1	961
¼ to 1 inch	LP	.6	.7	0	.3	.9	1,429
	S-F	.8	.9	.3	.5	1.1	132
	All	.7	.8	0	.3	1.1	2,706
	PP	.6	1.8	0	0	0	
	DF	1.3	2.5	0	0	2.1	
1 to 3 inch	LP	1.3	2.4	0	0	2.1	
	S-F	2.1	4.0	0	0	2.3	
	All	1.3	2.5	0	0	2.1	
	PP	3.9	16.1	0	0	1.2	
	DF	8.3	18.0	0	0	8.4	
Large	LP	10.4	19.3	0	2.3	13.0	
	S-F	21.3	22.1	4.5	15.7	32.8	
	All	9.7	19.0	0	1.3	11.4	
	PP	5	16	0	1	4	
	DF	10	19	0	3	12	
Total woody material	LP	12	20	1	5	15	
	S-F	24	23	6	17	38	
	All	12	20	0	4	14	
		Inches					
	PP	0.6	0.8	0	0.3	0.9	
	DF	.8	.9	0	.4	1.3	
Duff depth	LP	.9	1.1	.1	.6	1.3	
	S-F	1.3	1.6	.2	.8	1.8	
	All	.9	1.1	.1	.5	1.3	
		Tons/acre					
		Kaniksu National Forest					
	DF	1.4	1.1	0.5	1.1	2.1	99
	LP	1.2	1.0	.5	.9	1.7	99
¼ to 1 inch	L	1.0	1.1	0	.8	1.6	756
	S-F	1.1	1.1	.3	.8	1.5	498
	C-H	1.0	1.0	.3	.8	1.4	443
	All	1.1	1.1	0	.8	1.6	1,895
	DF	1.8	2.7	0	0	2.2	
	LP	2.5	4.0	0	0	4.3	
1 to 3 inch	L	1.7	3.0	0	0	2.2	
	S-F	1.9	3.2	0	0	2.2	
	C-H	1.9	3.2	0	0	2.2	
	All	1.9	3.4	0	0	2.2	
	DF	21.8	29.6	0	10.4	33.2	
	LP	13.8	24.2	0	3.1	14.8	
Large	L	24.6	34.9	0	9.0	36.4	
	S-F	24.5	34.6	0	10.5	36.4	
	C-H	25.7	33.9	1.2	13.1	38.1	
	All	20.8	36.9	0	6.2	27.8	
	DF	25	30	3	13	34	
	LP	18	25	2	8	21	
Total woody material	L	27	35	3	13	39	
	S-F	27	36	3	14	39	
	C-H	29	35	4	16	41	
	All	24	38	2	10	31	
		Inches					
	DF	1.5	1.5	0.4	1.0	2.2	
	LP	2.1	2.6	.5	1.0	2.3	
Duff depth	L	1.3	1.6	.2	.8	1.8	
	S-F	1.3	1.6	.3	.8	1.8	
	C-H	1.3	1.6	.3	.8	1.8	
	All	1.3	1.7	.1	.8	1.8	

(Con.)

Table 9. — (Con.)

Fuel category	Cover type	Mean	Standard deviation	First quartile	Median	Third quartile	Number points
		Tons/acre					
		Kootenai National Forest					
¼ to 1 inch	PP	0.5	0.8	0	0.3	0.8	150
	DF	1.1	1.2	.3	.8	1.6	960
	LP	1.0	1.1	.3	.6	1.4	1,061
	L	1.1	1.1	.3	.8	1.6	765
	S-F	.9	1.0	0	.5	1.4	393
	C-H	1.3	1.2	.3	.9	1.9	271
	All	1.0	1.1	.3	.6	1.4	3,600
1 to 3 inch	PP	1.4	2.7	0	0	2.1	
	DF	1.9	3.4	0	0	2.4	
	LP	2.1	3.3	0	0	2.5	
	L	2.2	3.6	0	0	2.5	
	S-F	2.0	3.3	0	0	2.4	
	C-H	2.2	3.7	0	0	2.6	
	All	2.0	3.4	0	0	2.4	
Large	PP	5.9	19.6	0	0	2.8	
	DF	10.9	22.2	0	1.6	13.7	
	LP	14.4	26.3	0	4.3	18.1	
	L	20.8	31.6	0	9.3	27.6	
	S-F	26.0	46.2	0	6.8	33.2	
	C-H	35.6	64.3	0	13.3	44.6	
	All	17.3	34.1	0	4.4	21.0	
Total woody material	PP	8	20	0	1	7	
	DF	14	23	1	5	17	
	LP	17	27	2	8	22	
	L	24	32	4	13	33	
	S-F	29	47	2	11	36	
	C-H	39	65	4	17	49	
	All	20	35	2	8	25	
		Inches					
Duff Depth	PP	0.9	1.2	0	0.5	1.5	
	DF	1.3	1.4	.3	1.0	1.8	
	LP	1.5	1.6	.4	1.1	2.0	
	L	1.7	1.6	.6	1.4	2.3	
	S-F	1.6	2.1	0	.9	2.5	
	C-H	2.2	2.5	.5	1.5	2.9	
	All	1.5	1.7	.3	1.1	2.1	
		Tons/acre					
		Lolo National Forest					
¼ to 1 inch	PP	0.9	1.1	0	0.5	1.7	120
	DF	1.2	1.4	.3	.9	1.7	1,000
	LP	1.1	1.1	.3	.8	1.6	768
	L	1.4	1.4	.5	.9	2.1	176
	S-F	1.0	1.1	.3	.6	1.4	837
	C-H	1.4	1.2	.3	1.3	1.9	49
	All	1.1	1.2	.3	.8	1.6	2,950
1 to 3 inch	PP	1.3	2.6	0	0	2.2	
	DF	1.4	2.9	0	0	2.3	
	LP	2.4	3.7	0	0	2.6	
	L	1.9	2.8	0	0	2.4	
	S-F	1.6	2.9	0	0	2.3	
	C-H	1.6	2.2	0	0	2.4	
	All	1.8	3.1	0	0	2.4	
Large	PP	4.8	15.8	0	0	1.9	
	DF	11.5	23.1	0	1.3	13.2	
	LP	13.3	21.8	0	3.5	17.6	
	L	16.9	34.6	0	6.4	18.2	
	S-F	21.0	38.3	0	6.7	28.8	
	C-H	17.9	31.7	0	2.1	19.1	
	All	14.8	28.9	0	3.0	18.5	
Total woody material	PP	7	16	0	2	7	
	DF	14	24	1	4	18	
	LP	17	23	2	8	22	
	L	20	35	4	10	24	
	S-F	24	39	2	11	32	
	C-H	21	33	2	6	21	
	All	18	30	1	7	22	
		Inches					
Duff depth	PP	0.5	0.6	0	0.3	0.8	
	DF	1.1	1.4	.3	.8	1.4	
	LP	1.2	1.2	.3	.9	1.8	
	L	1.5	1.5	.4	1.3	1.9	
	S-F	1.3	1.5	.2	.9	1.9	
	C-H	1.2	1.5	0	.8	1.5	
	All	1.2	1.3	.3	.8	1.6	

(Con.)

Table 9. — (Con.

Fuel category	Cover type	Mean	Standard deviation	First quartile	Median	Third quartile	Number points
		Tons/acre					
		Nezperce National Forest					
¼ to 1 inch	PP	1.1	1.3	0	0.7	1.5	257
	DF	1.1	1.1	.3	.9	1.6	611
	LP	.8	.9	0	.6	1.2	499
	L	1.2	1.2	.3	.9	1.7	639
	S-F	.8	1.0	0	.5	1.1	189
	C-H	1.8	1.3	.8	1.6	2.3	75
	All	1.1	1.1	.3	.8	1.6	2,270
1 to 3 inch	PP	1.4	2.8	0	0	2.4	
	DF	1.9	3.4	0	0	2.6	
	LP	1.7	3.0	0	0	2.3	
	L	1.8	3.2	0	0	2.3	
	S-F	1.7	3.5	0	0	2.2	
	C-H	3.2	3.3	0	2.4	4.6	
	All	1.8	3.2	0	0	2.4	
Large	PP	10.7	20.9	0	0	12.9	
	DF	14.5	29.3	0	1.4	17.6	
	LP	14.8	26.0	0	4.9	19.2	
	L	22.1	34.8	0	5.5	32.4	
	S-F	17.7	27,5	0	4.2	26.2	
	C-H	22.9	29.9	1.6	9.6	33	
	All	16.8	29.6	0	3.1	21.9	
Total woody material	PP	13	22	0	3	17	
	DF	18	30	1	5	22	
	LP	17	27	1	9	22	
	L	25	36	1	9	36	
	S-F	20	29	0	7	28	
	C-H	28	30	8	17	40	
	All	20	31	1	7	26	
		Inches					
Duff depth	PP	0.6	1.3	0	0.2	.7	
	DF	.7	1.1	0	.3	.9	
	LP	.6	.9	0	.3	.8	
	L	.8	1.0	.1	.5	1.1	
	S-F	.9	1.4	0	.3	1.3	
	C-H	1.3	1.1	.6	1.0	2.0	
	All	.7	1.1	0	.4	1.0	
		Tons/acre					
		St. Joe National Forest					
¼ to 1 inch	DF	1.1	1.1	0.3	0.8	1.6	321
	LP	1.1	1.0	.3	.8	1.6	149
	L	.8	1.0	0	.5	1.3	221
	S-F	1.0	1.2	0	.5	1.6	136
	C-H	.9	1.0	0	.5	1.6	139
	All	1.0	1.1	0	.8	1.6	966
1 to 3 inch	DF	1.8	2.9	0	0	2.1	
	LP	2.5	2.8	0	2.1	4.3	
	L	2.3	3.8	0	0	4.3	
	S-F	2.0	3.5	0	0	2.1	
	C-H	1.8	2.8	0	0	2.1	
	All	2.1	3.2	0	0	2.1	
Large	DF	11.9	26.0	0	0	13.0	
	LP	15.6	17.8	1.2	8.9	28.7	
	L	12.4	21.6	0	0	18.8	
	S-F	22.5	37.0	0	3.4	31.9	
	C-H	21.9	46.8	0	4.8	22.0	
	All	15.5	30.1	0	2.7	19.4	
Total woody material	DF	15	27	1	5	17	
	LP	19	19	5	13	29	
	L	15	23	0	6	23	
	S-F	26	38	0	10	36	
	C-H	25	48	0	9	31	
	All	19	31	1	7	25	
		Inches					
Duff depth	DF	0.7	0.9	0	0.4	1.0	
	LP	.9	1.0	.2	.7	1.3	
	L	.6	1.0	0	.2	.7	
	S-F	.6	1.1	0	.2	.7	
	C-H	.9	1.3	0	.4	1.5	
	All	.7	1.1	0	.4	1.0	

(Con.)

Table 9. — (Con.)

Fuel category	Cover type	Mean	Standard deviation	First quartile	Median	Third quartile	Number points
		Tons/Acre					
		Eastside Forests					
¼ to 1 inch	PP	0.5	0.7	0	0	0.6	184
	DF	.8	.9	0	.5	1.1	2,475
	LP	.7	.8	0	.5	.9	3,400
	S-F	.8	1.0	0	.5	1.2	712
	All	.7	.9	0	.5	1.1	6,771
1 to 3 inch	PP	.6	1.8	0	0	0	
	DF	1.6	3.2	0	0	2.2	
	LP	1.5	2.7	0	0	2.2	
	S-F	1.7	3.1	0	0	2.2	
	All	1.5	2.9	0	0	2.2	
Large	PP	3.9	16.1	0	0	1.2	
	DF	9.6	19.6	0	1.2	11.7	
	LP	13.9	26.6	0	4.7	18.2	
	S-F	20.2	26.9	0	11.2	29.0	
	All	12.8	24.3	0	3.3	16.8	
Total woody material	PP	5	16	0	1	4	
	DF	12	21	1	4	15	
	LP	16	27	1	7	22	
	S-F	23	28	2	14	33	
	All	15	25	1	6	20	
		Inches					
Duff depth	PP	0.6	0.8	0	0.3	0.9	
	DF	1.0	1.1	.1	.7	1.5	
	LP	1.1	1.2	.2	.8	1.6	
	S-F	1.3	1.6	.2	.9	1.9	
	All	1.1	1.2	.2	.7	1.6	
		Tons/acre					
		Westside Forests					
¼ to 1 inch	PP	0.9	1.4	0	0.5	1.1	944
	DF	1.0	1.2	0	.7	1.6	5,762
	LP	1.0	1.1	.3	.6	1.4	4,172
	L	1.3	1.2	.3	.9	1.9	5,381
	S-F	1.0	1.1	0	.6	1.4	3,597
	C-H	1.3	1.2	.3	1.0	1.9	1,727
	All	1.1	1.2	—	.8	—	21,584
1 to 3 inch	PP	1.6	3.9	0	0	2.2	
	DF	1.8	3.4	0	0	2.4	
	LP	2.1	3.7	0	0	2.4	
	L	2.3	3.8	0	0	2.7	
	S-F	1.9	3.3	0	0	2.3	
	C-H	2.7	4.4	0	0	4.3	
	All	2.1	3.7	—	0	—	
Large	PP	10.4	23.3	0	0	8.3	
	DF	12.9	24.9	0	1.6	15.9	
	LP	14.4	24.1	0	4.2	19.4	
	L	17.7	28.4	0	5.9	23.5	
	S-F	23.8	38.6	0	8.6	33.4	
	C-H	29.4	48.8	0	12.5	38.6	
	All	17.4	31.2	—	4.4	—	
Total woody material	PP	13	25	0	2	14	
	DF	16	26	1	5	20	
	LP	18	25	2	8	24	
	L	21	29	2	10	29	
	S-F	27	39	2	12	37	
	C-H	33	50	4	17	43	
	All	21	32	—	9	—	
		Inches					
Duff depth	PP	0.6	1.1	0	0.2	0.8	
	DF	.9	1.2	0	.5	1.3	
	LP	1.1	1.3	.2	.7	1.5	
	L	1.2	1.4	.2	.8	1.6	
	S-F	1.4	1.7	.1	.8	2.0	
	C-H	1.4	1.9	.1	.8	2.0	
	All	1.1	1.5	—	.7	—	

Table 10.—Loadings of downed woody material and depths of forest floor duff by National Forests and habitat type groups from Forest Survey data

Fuel category	Habitat type group	Mean	Standard deviation	First quartile	Median	Third quartile	Number points
		Tons/acre					
		Bitterroot National Forest					
¼ to 1 inch	2	0.5	0.8	0	0	0.8	226
	3	.5	.8	0	0	.8	504
	4	.5	.9	0	0	.5	691
	5	.4	.6	0	0	.5	210
1 to 3 inch	2	1.2	2.7	0	0	2.1	
	3	1.1	2.7	0	0	0	
	4	1.2	2.8	0	0	0	
	5	1.1	2.2	0	0	2.1	
Large	2	9.5	16.3	0	.6	14.9	
	3	7.2	16.5	0	0	7.1	
	4	10.7	21.1	0	0	12.5	
	5	12.7	20.3	0	0	17.6	
Total woody material	2	11	18	0	2	16	
	3	9	18	0	0	11	
	4	12	22	0	1	16	
	5	14	22	0	2	20	
		Inches					
Duff depth	2	0.6	0.9	0	0.1	1.0	
	3	.5	.9	0	0	.6	
	4	.5	1.1	0	0	.5	
	5	.5	.9	0	0	.6	
		Tons/acre					
		Clearwater National Forest					
¼ to 1 inch	3	2.0	1.4	0.9	1.6	2.6	30
	4	.9	1.1	0	.6	1.3	515
	5	1.2	1.2	.3	.9	1.7	821
	7	1.4	1.3	.5	1.1	2.1	1,086
1 to 3 inch	3	1.6	3.4	0	0	2.4	
	4	1.6	3.4	0	0	2.2	
	5	2.0	3.9	0	0	2.4	
	7	3.6	5.7	0	2.2	5.0	
Large	3	4.3	10.0	0	0	3.3	
	4	10.2	23.8	0	0	11.8	
	5	17.4	31.9	0	2.1	22.4	
	7	19.1	32.3	0	2.8	26.2	
Total woody material	3	8	11	2	4	11	
	4	13	25	0	3	15	
	5	21	33	1	7	27	
	7	24	34	2	11	32	
		Inches					
Duff depth	3	0.2	0.3	0	0.1	0.3	
	4	.5	1.1	0	.1	.5	
	5	1.1	1.4	.1	.5	1.5	
	7	1.0	1.5	.1	.5	1.5	

(Con.)

Table 10.—(Con.)

Fuel category	Habitat type group	Mean	Standard deviation	First quartile	Median	Third quartile	Number points
		Tons/acre					
		Colville National Forest					
	2	1.3	1.3	0.3	1.0	2.0	1,703
¼ to 1 inch	3	1.5	1.2	.6	1.3	2.2	249
	4	1.3	1.2	.3	1.1	2.0	741
	5	1.6	1.3	.5	1.3	2.4	643
	2	3.0	4.9	0	2.1	4.4	
	3	2.2	3.4	0	0	2.3	
1 to 3 inch	4	2.5	3.9	0	2.1	4.3	
	5	2.9	4.2	0	2.1	4.5	
	2	20.0	32.4	0	6.6	26.9	
	3	16.4	24.4	0	5.5	21.4	
Large	4	26.1	37.8	0	11.2	36.4	
	5	17.5	24.4	0	8.3	26.4	
Total	2	24	34	3	12	33	
woody	3	20	25	2	11	27	
material	4	30	39	4	16	42	
	5	22	26	4	14	32	
		Inches					
	2	0.8	1.1	0.1	0.5	1.2	
Duff	3	1.0	1.2	.3	.8	1.4	
depth	4	1.5	1.5	.3	1.0	2.2	
	5	1.2	1.3	.3	.9	1.6	
		Tons/acre					
		Deerlodge National Forest					
	1	0.8	0.9	0	0.5	1.1	186
	2	.8	.9	0	.5	1.1	757
¼ to 1 inch	3	.7	.9	0	.3	.9	254
	4	.7	.9	0	.5	1.1	766
	5	.6	.7	0	.3	.8	458
	6	.7	.9	0	.5	.8	181
	1	1.8	3.3	0	0	2.2	
	2	1.7	3.0	0	0	2.2	
	3	1.3	2.8	0	0	2.1	
1 to 3 inch	4	1.7	2.8	0	0	2.2	
	5	1.7	2.8	0	0	2.2	
	6	1.5	2.3	0	0	2.2	
	1	14.6	22.0	0	5.9	20.2	
	2	9.7	18.3	0	1.5	12.6	
	3	18.7	24.4	0	9.8	26.1	
Large	4	18.6	25.7	0	10.1	27.1	
	5	14.4	33.6	0	6.3	19.1	
	6	9.2	14.1	0	3.3	12.4	
	1	17	23	1	9	21	
	2	12	19	1	5	17	
Total	3	21	25	2	12	29	
woody	4	21	26	3	13	30	
material	5	17	34	1	9	22	
	6	11	15	1	5	16	
		Inches					
	1	1.3	1.0	0.4	1.2	1.8	
	2	1.0	1.1	.2	.8	1.6	
Duff	3	1.5	1.6	.4	1.0	2.2	
depth	4	1.5	1.4	.4	1.2	2.1	
	5	1.2	1.3	.3	.9	1.8	
	6	.9	1.1	.1	.5	1.5	

Fuel category	Habitat type group	Mean	Standard deviation	First quartile	Median	Third quartile	Number points
		Tons/acre					
		Flathead National Forest					
¼ to 1 inch	2	0.6	0.7	0	0.3	0.9	45
	3	1.0	1.1	.3	.6	1.4	251
	4	1.0	1.1	.3	.6	1.4	436
	5	1.0	1.0	.3	.7	1.4	1,188
	6	1.0	1.1	0	.8	1.4	123
	7	1.2	1.1	.3	.9	1.6	406
1 to 3 inch	2	1.6	2.5	0	0	2.3	
	3	2.0	3.0	0	0	2.4	
	4	2.2	4.1	0	0	2.3	
	5	1.9	3.1	0	0	2.3	
	6	1.7	3.5	0	0	2.2	
	7	2.1	4.0	0	0	2.3	
Large	2	20.0	28.6	0	8.3	23.9	
	3	13.2	22.0	0	4.9	16.3	
	4	17.4	23.7	0	8.0	26.8	
	5	23.0	31.9	0	11.3	32.8	
	6	27.3	52.2	1.2	14.6	33.8	
	7	21.5	29.2	1.3	11.3	29.7	
Total woody material	2	22	29	2	11	28	
	3	16	23	2	8	20	
	4	21	25	2	11	32	
	5	26	33	3	14	38	
	6	30	52	4	18	36	
	7	25	30	5	15	34	
		Inches					
Duff depth	2	0.9	0.8	0.2	0.9	1.2	
	3	.9	1.0	.3	.8	1.3	
	4	1.3	1.5	.3	.8	1.7	
	5	1.7	1.7	.5	1.3	2.3	
	6	2.0	1.5	.9	1.6	2.9	
	7	1.6	1.7	.5	1.3	2.2	
		Tons/acre					
		Gallatin National Forest					
¼ to 1 inch	1	0.5	0.8	0	0.3	0.7	39
	2	.7	.8	0	.5	.8	54
	3	1.0	1.1	.3	.7	1.3	274
	4	.9	.9	.3	.6	1.2	847
	5	1.1	1.1	.3	.9	1.6	128
	6	.8	.8	.3	.8	1.1	112
1 to 3 inch	1	.7	1.4	0	0	0	
	2	.9	1.5	0	0	2.2	
	3	1.7	3.6	0	0	2.2	
	4	2.0	4.0	0	0	2.2	
	5	1.9	2.8	0	0	2.4	
	6	1.2	2.4	0	0	2.1	
Large	1	6.2	16.6	0	0	3.7	
	2	5.7	12.4	0	0	4.4	
	3	6.9	13.1	0	0	8.5	
	4	17.9	29.2	0	6.4	24.6	
	5	24.2	50.0	1.4	13.9	25.1	
	6	17.8	45.3	0	4.9	17.1	
Total woody material	1	7	17	0	1	5	
	2	7	13	1	3	7	
	3	10	14	1	4	13	
	4	21	31	2	10	29	
	5	27	52	4	16	30	
	6	20	46	1	6	22	
		Inches					
Duff depth	1	0.6	0.9	0	0.1	0.9	
	2	.8	.7	.1	.5	1.2	
	3	1.1	1.4	.2	.7	1.5	
	4	1.1	1.3	.2	.8	1.6	
	5	1.5	1.4	.5	1.2	2.1	
	6	1.0	1.4	.2	.5	1.3	

(Con.)

Table 10.—(Con.)

Fuel category	Habitat type group	Mean	Standard deviation	First quartile	Median	Third quartile	Number points
		Tons/acre					
		Helena National Forest					
¼ to 1 inch	1	0.4	0.7	0	0	0.6	352
	2	.8	.9	0	.5	1.1	423
	3	.7	.9	0	.5	1.1	623
	4	.6	.8	0	.5	.9	786
	5	.8	.9	.3	.5	1.1	284
	6	.6	.7	0	.3	.8	229
1 to 3 inch	1	.7	2.1	0	0	0	
	2	1.2	2.4	0	0	2.1	
	3	1.3	2.5	0	0	2.1	
	4	1.5	2.9	0	0	2.2	
	5	1.7	2.7	0	0	2.2	
	6	.8	1.6	0	0	2.1	
Large	1	2.9	8.4	0	0	1.2	
	2	11.9	23.1	0	1.4	14.3	
	3	7.4	17.5	0	0	8.3	
	4	11.2	18.8	0	2.9	15.9	
	5	15.5	20.6	1.2	8.1	21.2	
	6	9.9	21.4	0	0	11.2	
Total woody material	1	4	9	0	0	4	
	2	14	24	1	4	16	
	3	10	18	1	3	11	
	4	13	19	1	6	19	
	5	18	21	3	11	26	
	6	11	22	0	3	14	
		Inches					
Duff depth	1	0.4	0.8	0	0	0.5	
	2	.7	.8	0	.4	1.0	
	3	1.1	1.1	.2	.8	1.6	
	4	.9	1.2	.1	.6	1.3	
	5	1.3	1.3	.3	1.1	2.0	
	6	.8	1.0	0	.3	1.1	
		Tons/acre					
		Kaniksu National Forest					
¼ to 1 inch	2	1.0	1.3	0	0.2	1.8	10
	3	.8	1.0	0	.5	1.2	242
	4	1.1	1.0	.4	.9	1.6	72
	5	.9	.9	.3	.8	1.4	256
	7	1.1	1.1	.3	.8	1.7	1,315
1 to 3 inch	2	1.8	2.6	0	0	4.3	
	3	1.2	2.5	0	0	2.1	
	4	2.6	3.8	0	0	3.3	
	5	1.9	3.3	0	0	2.2	
	7	2.1	3.5	0	0	2.3	
Large	2	4.2	13.3	0	0	0	
	3	6.8	15.2	0	0	6.3	
	4	19.2	31.2	0	4.3	28.2	
	5	23.1	27.1	1.6	13.3	34.2	
	7	23.5	40.9	0	7.5	30.5	
Total woody material	2	7	15	0	0	8	
	3	9	16	0	2	10	
	4	23	31	3	9	30	
	5	26	28	5	17	37	
	7	26	42	3	11	35	
		Inches					
Duff depth	2	0.8	0.9	0	0.8	1.7	
	3	.9	1.1	0	.5	1.3	
	4	1.1	1.6	.3	.7	1.4	
	5	1.3	1.8	.2	.7	1.7	
	7	1.5	1.8	.2	.9	2.0	

(C

Table 10.—(Con.)

Fuel category	Habitat type group	Mean	Standard deviation	First quartile	Median	Third quartile	Number points
		Tons/acre					
		Kootenai National Forest					
¼ to 1 inch	2	1.0	1.0	0	0.3	0.9	340
	3	.9	1.1	0	.5	1.3	803
	4	1.0	1.0	.3	.6	1.4	516
	5	.9	1.0	0	.5	1.4	617
	6	.3	.6	0	0	.3	21
	7	1.3	1.2	.3	.9	1.8	1,302
1 to 3 inch	2	1.9	3.2	0	0	2.2	
	3	1.7	3.3	0	0	2.3	
	4	2.2	3.5	0	0	2.5	
	5	2.0	3.7	0	0	2.2	
	6	.7	1.3	0	0	0	
	7	2.2	3.3	0	0	4.3	
Large	2	13.6	18.4	0	0	7.5	
	3	9.1	17.1	0	1.2	10.8	
	4	19.1	30.4	0	6.2	25.2	
	5	20.2	34.3	0	6.3	24.8	
	6	5.9	13.5	0	0	6.9	
	7	23.0	43.7	0	8.6	27.6	
Total woody material	2	17	19	0	3	11	
	3	12	19	1	4	16	
	4	22	31	3	11	29	
	5	23	35	2	10	30	
	6	7	13	0	2	9	
	7	27	44	4	12	32	
		Inches					
Duff depth	2	1.2	1.0	0	0.5	1.3	
	3	1.3	1.3	.2	1.0	1.8	
	4	1.6	1.7	.4	1.1	2.2	
	5	1.6	1.8	.1	1.1	2.3	
	6	.6	1.2	0	0	.5	
	7	1.9	1.9	.6	1.4	2.5	
		Tons/acre					
		Lolo National Forest					
¼ to 1 inch	2	0.9	1.2	0	0.6	1.3	275
	3	1.0	1.1	.3	.6	1.5	780
	4	1.2	1.2	.3	.9	1.8	842
	5	1.1	1.1	.3	.8	1.5	609
	6	.8	.9	0	.6	1.1	183
	7	1.5	1.9	.5	1.1	2.0	261
1 to 3 inch	2	1.2	2.8	0	0	2.2	
	3	1.4	2.8	0	0	2.3	
	4	2.2	3.4	0	0	2.5	
	5	1.7	2.9	0	0	2.3	
	6	1.3	2.5	0	0	2.2	
	7	2.2	3.9	0	0	2.5	
Large	2	7.3	19.6	0	0	4.3	
	3	9.0	17.5	0	1.2	9.8	
	4	16.6	29.5	0	3.8	20.2	
	5	25.3	43.2	0	10.8	33.1	
	6	8.8	13.7	0	1.7	11.8	
	7	14.3	20.5	0	5.6	20.0	
Total woody material	2	9	21	0	2	9	
	3	11	18	1	4	15	
	4	20	30	2	9	25	
	5	28	44	3	14	36	
	6	11	14	1	5	15	
	7	18	21	4	9	26	
		Inches					
Duff depth	2	0.7	1.1	0	0.4	1.1	
	3	1.1	1.2	.3	.8	1.4	
	4	1.3	1.3	.3	.9	1.8	
	5	1.4	1.5	.3	.10	1.8	
	6	.9	.9	.2	.6	1.4	
	7	1.6	1.8	.5	1.1	2.0	

(Con.)

Table 10.—(Con.)

Fuel category	Habitat type group	Mean	Standard deviation	First quartile	Median	Third quartile	Number points
		Tons/acre					
		Nezperce National Forest					
¼ to 1 inch	2	0.4	.07	0	0	0.7	20
	3	1.1	1.2	.3	.7	1.4	380
	4	1.0	1.1	.3	.7	1.4	891
	5	1.0	1.1	0	.8	1.5	178
	6	.6	.8	0	.3	.9	145
	7	1.3	1.1	.5	1.0	1.8	656
1 to 3 inch	2	.1	.6	0	0	0	
	3	1.4	2.8	0	0	2.5	
	4	1.8	3.3	0	0	2.3	
	5	1.5	2.8	0	0	2.2	
	6	1.2	2.1	0	0	2.2	
	7	2.3	3.5	0	0	2.7	
Large	2	5.2	22.7	0	0	0	
	3	13.8	30.0	0	0	14.9	
	4	17.7	27.8	0	5.6	25.9	
	5	19.1	34.8	0	2.1	23.5	
	6	11.3	18.6	0	0	17.8	
	7	8.4	32.0	0	3.5	24.7	
Total woody material	2	6	23	0	0	1	
	3	16	31	1	3	20	
	4	21	29	1	9	29	
	5	22	36	1	5	26	
	6	13	20	0	3	18	
	7	22	33	2	8	29	
		Inches					
Duff depth	2	0.3	0.7	0	0	0.4	
	3	.5	1.0	0	.2	.5	
	4	.8	1.1	.1	.5	1.1	
	5	.7	1.1	0	.2	.9	
	6	.3	.7	0	0	.4	
	7	.9	1.2	.1	.5	1.3	
		Tons/acre					
		St. Joe National Forest					
¼ to 1 inch	3	1.0	1.0	0.3	0.8	1.3	52
	5	1.0	1.2	0	.5	1.6	191
	7	1.0	1.1	0	.8	1.6	720
1 to 3 inch	3	1.3	1.9	0	0	2.1	
	5	.8	2.9	0	0	2.1	
	7	2.2	3.3	0	0	4.3	
Large	3	9.3	33.4	0	0	1.5	
	5	22.2	34.6	0	7.6	30.8	
	7	14.2	28.3	0	2.1	18.8	
Total woody material	3	12	34	1	2	6	
	5	25	35	2	11	36	
	7	17	29	0	7	23	
		Inches					
Duff depth	3	0.4	0.6	0	0.2	0.6	
	5	.6	1.1	0	.3	.9	
	7	.8	1.1	0	.4	1.0	

(Con.)

Table 10.—(Con.)

Fuel category	Habitat type group	Mean	Standard deviation	First quartile	Median	Third quartile	Number points
		Tons/acre					
		Eastside Forests					
¼ to 1 inch	1	0.7	0.8	0	0.5	1.1	577
	2	.9	1.0	0	.6	1.2	1,234
	3	.7	1.0	0	.3	1.1	1,151
	4	.7	.9	0	.5	1.1	2,320
	5	.6	.8	0	.3	.9	870
	6	.6	.7	0	.5	.8	123
1 to 3 inch	1	1.6	2.9	0	0	2.2	
	2	1.6	3.6	0	0	2.2	
	3	1.4	2.7	0	0	2.1	
	4	1.7	3.0	0	0	2.2	
	5	1.3	2.5	0	0	2.2	
	6	1.5	2.4	0	0	2.2	
Large	1	8.5	16.8	0	1.2	10.8	
	2	10.5	21.4	0	1.6	12.5	
	3	11.3	20.6	0	1.3	14.5	
	4	17.0	30.2	0	7.3	23.2	
	5	16.9	17.2	0	2.1	10.6	
	6	9.4	14.9	0	1.6	12.6	
Total woody material	1	11	18	0	4	14	
	2	13	23	1	5	16	
	3	13	22	0	4	18	
	4	19	31	2	10	27	
	5	19	18	1	5	13	
	6	12	15	1	6	15	
		Inches					
Duff depth	1	1.1	1.1	0.2	0.8	1.6	
	2	1.0	1.1	.2	.7	1.5	
	3	.9	1.2	.1	.6	1.4	
	4	1.2	1.3	.3	.9	1.8	
	5	1.0	1.2	.1	.6	1.4	
	6	.7	.9	.1	.3	1.0	
		Tons/acre					
		Westside Forests					
¼ to 1 inch	2	1.1	1.2	0	0.8	1.7	2,569
	3	.9	1.1	0	.6	1.4	3,287
	4	1.1	1.2	.3	.8	1.6	5,348
	5	1.0	1.1	.3	.7	1.4	3,937
	6	.8	1.0	0	.5	1.1	474
	7	1.2	1.2	.3	.9	1.9	5,460
1 to 3 inch	2	2.5	4.4	0	0	4.3	
	3	1.5	2.9	0	0	2.2	
	4	2.1	3.6	0	0	2.4	
	5	1.8	3.3	0	0	2.3	
	6	1.3	2.6	0	0	2.2	
	7	2.4	4.1	0	0	4.3	
Large	2	15.9	29.2	0	3.0	19.1	
	3	10.0	20.4	0	0	11.0	
	4	17.3	28.4	0	4.8	23.7	
	5	21.0	33.8	0	7.8	29.4	
	6	14.3	30.8	0	3.4	19.7	
	7	20.3	36.9	0	5.9	26.0	
Total woody material	2	19	31	1	8	24	
	3	12	21	0	4	16	
	4	21	29	1	9	28	
	5	24	35	2	11	33	
	6	16	31	1	6	22	
	7	24	38	3	11	30	
		Inches					
Duff depth	2	0.8	1.0	0	0.4	1.1	
	3	.9	1.1	0	.5	1.3	
	4	1.1	1.4	.1	.6	1.5	
	5	1.4	1.6	.2	.9	1.9	
	6	1.0	1.2	0	.5	1.5	
	7	1.3	1.7	.2	.9	1.8	

APPENDIX II

Variation in Data and Correlation Between Fuel Variables

Variation in the Data

Distribution of one-fourth to 1-inch (0.25 to 2.5-cm), 1- to 3-inch (2.6- to 7.5-cm), and over 3-inch (7.6-cm) diameter downed woody loadings were examined for many subsets of the data. In all cases, a high degree of variation was found. The distributions were highly skewed, all having long right-handed tails and many zero observations as is illustrated in figure 13. The high degree of variation is partly due to sampling with short transects as the basis for observation. Essentially, sampling was done with very small plots. Additionally, downed woody material is unevenly distributed over the forest floor; a sample transect may have occurrences of no fuel or of jackpots of material. The jackpots cause very high loadings on some points, thus, creating the long-tailed distributions. These high loadings inordinately affect means, which overestimate the center of loading distributions. The mean and standard deviation present a distributional picture that can be misleading.

For these reasons, tables 9 and 10 include the quartiles (Q1, 25th percentile; Q2, 50th percentile or median; and Q3, 75th percentile) as statistics that might reflect fuel loadings in a more realistic manner for evaluation of fire behavior potential. The second quartile, or median, is the halfway point of the ranked data. About 50 percent of the area has loadings less than this figure, while about 50 percent has greater loadings. In all data sets that we analyzed, medians were less than arithmetic means, again pointing out the positive skewness of the distributions. Total loadings ratios of medians to means calculated for combinations of cover types and National Forests averaged 0.43 and ranged from 0.11 to 0.80. The interquartile range, Q3 to Q1 (tables 9 and 10), is a measure of the variability of the ranked data. It shows the spread of the middle 50 percent of the data. For the fuel distributions, it is a more meaningful expression of variation than the standard deviation.

Correlations Among Fuel Variables

Relationships between fuel variables were examined using Kendall's and Spearman's nonparametric correlation analysis (Conover 1971). Practically all correlation coefficients were statistically significant due to large amounts of data. Spearman's correlation coefficients were 0.05 to 0.10 greater than those for Kendall. However, correlations were very low indicating little dependence among fuel variables (fig. 14). The practical implication is that quantities of one fuel class such as 1- to 3-inch (2.6- to 7.5-cm) downed woody material cannot be predicted satisfactorily from another fuel class.

The one-fourth to 1-inch (0.25- to 2.5-cm) and 1- to 3-inch (2.6- to 7.5-cm) variables had the highest correlation; nonetheless, the variables were only weakly related. This suggests that such factors as wind and snow breakage may influence downfall of twigs and small branches differently than large branches. Perhaps the rate that limbwood is incorporated into the forest floor duff differs by size of material. The ratio of one-fourth to 1-inch to 1- to 3-inch material averaged about 0.5 for all cover types. The ratio was 0.56 for ponderosa pine, 0.49 for Douglas-fir and spruce-fir, and 0.44 for cedar-hemlock, larch, and lodgepole pine.

Since 0- to one-fourth inch (0- to 0.25-cm) material was omitted from the Northern Region inventories, it could not be correlated with other variables. Extensive fuel loading data from a study in the Selway-Bitterroot Wilderness Area, however, indicated that the 0- to one-fourth inch (0- to 0.25-cm) material was poorly correlated with the one-fourth to 1-inch (0.25- to 2.5-cm) material. For these variables, Spearman's correlation coefficients ranged from 0.23 to 0.47 across six cover types.

Loading of small fuel was poorly correlated with either sound or rotten large fuel. Although not shown in figure 14, correlations between the sum of sound and rotten material and other fuel variables were equally as poor as those for sound and rotten categories alone.

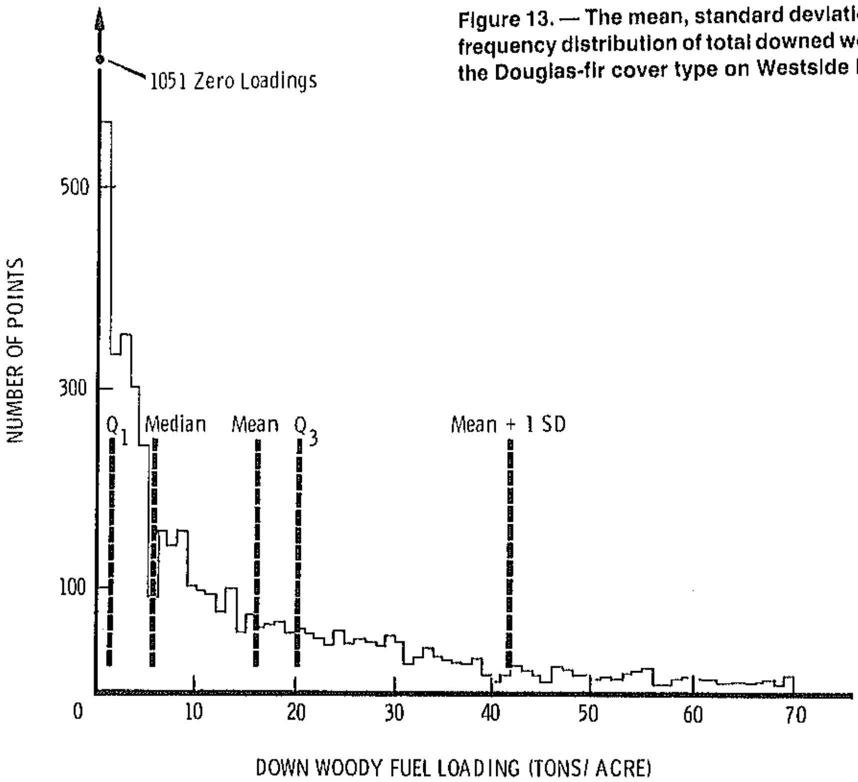

Figure 13. — The mean, standard deviation, quartiles, and frequency distribution of total downed woody loadings for the Douglas-fir cover type on Westside National Forests.

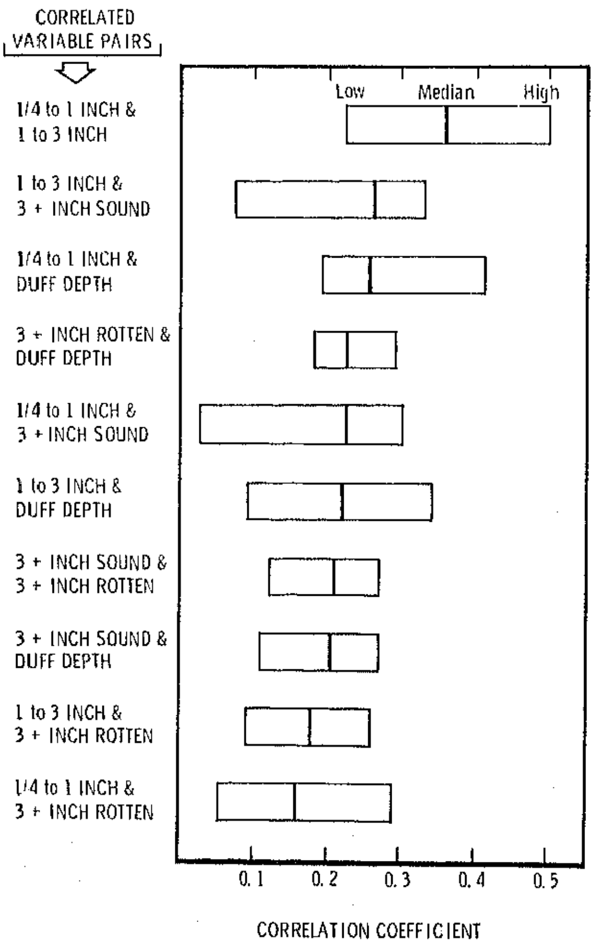

Figure 14. — Kendall's nonparametric correlation coefficients between pairs of fuel variables. The range and median of correlation coefficients from combinations of cover types and National Forests in the Northern Region are shown.

APPENDIX III

Formation of Habitat Type Groups

Habitat types were placed into groups (table 11) based on similarity of loading and correspondence to the habitat type fire groups developed by Davis and others (1980). (See appendix VIII for abbreviations of habitat types shown in table 11.) In the grouping by Davis and others, some habitat type phases were placed into different groups. We chose to place all phases of a habitat type into one group. Placement of habitat types into groups was based on the most commonly occurring phases. A few habitat types from the fire groups (Davis and others 1980) were placed in slightly different loading groups. For example, *Abies grandis/Xerophyllum tenax* from a warm moist fire group was placed in the dry lower subalpine fir loading group because fuel loading, productivity, and associated species were more like the latter group. For the Westside Forests, all dry-site ponderosa pine and Douglas-fir habitat types were placed in Group Two. However, for the Eastside Forests, ponderosa pine and Douglas-fir bunch grass habitat types were placed in Group One, while dry-site Douglas-fir habitat types were placed in Group Two. The ordination in figure 11 showed distinctly different loadings and productivities for the bunch grass types, thus a separate group seemed desirable. Apparently, limited stocking in the bunch grass types (Pfister and others 1977) resulted in lower productivities and loadings than other types on the Eastside. On the Westside, loadings and productivities of all dry-site habitat types seemed enough alike to justify one group (fig. 10).

The number of sample stands in table 11 indicates the relative occurrence of habitat types over the inventoried forest lands. On the Westside, the five most commonly occurring habitat types, *Abies lasiocarpa/Clintonia, Thuja/Clintonia, Pseudotsuga/Physocarpus, Tsuga heterophylla/Clintonia,* and *Abies lasiocarpa/Xerophyllum,* accounted for 53 percent of the sampled stands. On the Eastside, *Pseudotsuga/Calamagrostis rubescens, Abies lasiocarpa/Xerophyllum, Abies lasiocarpa/Pinus albicaulis - Vaccinium scoparium, Abies lasiocarpa/Vaccinium scoparium,* and *Pseudotsuga/Symphoricarpos albus* accounted for 40 percent of the stands. Most of the *Abies lasiocarpa/Xerophyllum* for the Eastside was from west of the Continental Divide.

Some habitat types fail to appear in table 11 because they were not sampled. To apply results of this paper to unmentioned habitat types, select the group that appears most similar ecologically. The fire groups by Davis and others (1980) will be helpful for this. Equivalence between the fire and loading habitat type groups is as follows:

Loading Groups	**Fire Groups** (Davis and others 1980)
1	1,2
2 Eastside	3,4,5
2 Westside	2,3,4,5
3	6
4	7,8
5	9
6	10
7	11

Table 11.—Groups of habitat types for relating to loading. Number of stands sampled is shown beside each habitat type (see appendix VIII for abbreviations of habitat types)

Groups[1]						
1 PIFL: PIPO and PSME bunch grass types	2 Dry-site PSME moist-site PIPO	3 Moist site PSME	4 Cool-site, PICO-dominated and dry, lower ABLA	5 Moist-site lower ABLA	6 Cold, moist-site upper ABLA	7 Warm, moist-sites
			WESTSIDE			
	PSME/CARU 118	PSME/PHMA 315	ABLA/XETE 264	ABLA/CLUN 337	ABLA/LUHI 73	THPL/CLUN 337
	PSME/FEID 29	PSME/VAGL 112	ABGR/XETE 122	ABLA/MEFE 182	PIAL/ABLA 9	TSHE/CLUN 276
	PSME/AGSP 26	PSME/SYAL 63	ABLA/VASC 61	TSME/MEFE 60	ABLA/RIMO 1	ABGR/CLUN 176
	PSME/FESC 11	PSME/LIBO 38	TSME/XETE 57	ABLA/LIBO 42	ABLA/PIAL 1	THPL/OPHO 8
	PSME/CAGE 7	PSME/VACA 34	ABLA/VACA 21	ABLA/ALSI 11		
	PSME/ARUV 3		PICEA/LIBO 20	PICEA/CLUN 8		
	PSME/SPBE 1		ABLA/VAGL 5	ABLA/OPHO 5		
	PIPO/AGSP 1		PICEA/VACA 2	ABLA/GATR 2		
	PIPO/SYAL 1		ABLA/CARU 1	ABLA/CACA 2		
			ABLA/CLPS 1			
			EASTSIDE			
PSME/FEID 47	PSME/CARU 136	PSME/SYAL 79	ABLA/XETE 117	ABLA/LIBO 54	ABLA-PIAL/VASC 113	
PIPO/FEID 36	PSME/JUCO 42	PSME/PHMA 67	ABLA/VASC 82	ABLA/MEFE 36	ABLA/LUHI 16	
PIPO/AGSP 27	PIPO/SYAL 35	PSME/LIBO 26	ABLA/VAGL 55	ABLA/CACA 25	PIAL/ABLA 15	
PIPO/AND 15	PSME/CAGE 19	PSME/VAGL 24	ABLA/CARU 23	ABLA/ALSI 19	PICEA/SEST 3	
PIFL/JUCO 10	PIPO/PRVI 16	PSME/VACA 8	ABLA/ARCO 22	ABLA/GATR 14	PIAL 3	
PSME/FESC 10	PSME/ARUV 13		ABLA/CLPS 16	PICEA/GATR 3	LALY/ABLA 1	
PIFL/FEID 8	PSME/ARCO 5		PICEA/LIBO 15	ABLA/CLUN 1		
PSME/AGSP 8	PSME/SPBE 4		PICO SERIES 15			
PIPO/PUTR 3			ABLA/VACA 10			
PIFL/AGSP 1			PICEA/SMST 8			
			PICEA/PHMA 7			
			ABLA/CAGE 4			

[1]1 = Limber pine (*Pinus flexilis*); ponderosa pine, and Douglas-fir/bunch grass types.
2 = Dry site Douglas-fir and moist site ponderosa pine.
3 = Moist site Douglas-fir.
4 = Cool sites dominated by lodgepole pine; dry, lower elevation subalpine fir.
5 = Moist site, lower elevation subalpine fir.
6 = Cold, moist site upper elevation subalpine fir.
7 = Warm, moist sites; mostly cedar-hemlock.

APPENDIX IV

Diameters of Large Downed Woody Material

The loadings of large material by diameter class were determined for five groups of habitat types selected from Forest Survey data to represent widely occurring cover types. Percentages of large material by diameter class are shown in table 12 for sound material and in table 13 for rotten material.

Table 12.—Percentages of sound downed woody material loadings by diameter class and habitat type within National Forests. Number of sample points are in parentheses

Habitat type[1]	Cover type[2]	Diameter	National Forest											
			Custer	Gallatin	Deerlodge	Helena	Beaverhead	Lolo	Bitterroot	Flathead	Kootenai	Nezperce	Clearwater	Kaniksu
		Inches	*Percent*											
ABLA/VASC ABLA/XETE	LP	3-6	65	14	19	29	23	20	13	24	14	15	14	13
		6-10	35	32	41	43	47	39	28	36	31	43	29	17
		10-20	0	54	30	28	29	31	17	36	50	36	47	70
		20+	0	0	10	0	1	10	42	4	5	6	10	0
			(33)	(285)	(607)	(615)	(1,001)	(444)	(159)	(422)	(311)	(397)	(349)	(121)
PSME/PHMA PSME/VAGL	DF	3-6	64	19	22	32	—	27	13	—	33	17	7	24
		6-10	22	26	64	32	—	39	22	—	28	23	50	25
		10-20	14	42	14	36	—	34	40	—	35	29	43	35
		20+	0	13	0	0	—	0	25	—	4	31	0	16
			(93)	(301)	(127)	(149)		(358)	(143)		(448)	(394)	(31)	(235)
THPL/CLUN TSHE/CLUN	C-H	3-6	—	8	—	—	—	19	—	19	16	9	9	13
		6-10	—	33	—	—	—	37	—	26	27	19	31	17
		10-20	—	59	—	—	—	44	—	48	36	51	46	43
		20+	—	0	—	—	—	0	—	7	21	21	14	27
				(47)				(122)		(119)	(1,203)	(228)	(910)	(1,473)
ABLA/CLUN ABLA/MEFE TSHE/MEFE	S-F	3-6	—	—	25	32	—	13	24	14	10	9	9	9
		6-10	—	—	39	46	—	35	68	29	22	23	18	21
		10-20	—	—	36	22	—	48	8	41	42	49	40	52
		20+	—	—	0	0	—	4	0	16	26	19	33	18
					(152)	(107)		(571)	(168)	(1,066)	(583)	(152)	(824)	(332)
ABGR/CLUN	L	3-6	—	27	—	—	—	15	—	13	25	13	15	—
		6-10	—	54	—	—	—	37	—	25	23	22	8	—
		10-20	—	19	—	—	—	48	—	52	14	35	35	—
		20+	—	0	—	—	—	0	—	10	38	30	42	—
				(82)				(139)		(321)	(136)	(395)	(212)	

[1]See appendix VIII for abbreviations for habitat types.

[2]1 = Limber pine q(*Pinus flexilis*); ponderosa pine, and Douglas-fir/bunch grass types.
2 = Dry site Douglas-fir and moist site ponderosa pine.
3 = Moist site Douglas-fir.
4 = Cool sites dominated by lodgepine; dry, lower elevation subalpine fir.
5 = Moist site, lower elevation subalpine fir.
6 = Cold, moist site upper elevation subalpine fir.
7 = Warm, moist sites; mostly cedar-hemlock.

Table 13.—Percentages of rotten downed woody material loadings by diameter class and habitat type within National Forests. Number of sample points are in parentheses.

Habitat type[1]	Cover type[2]	Diameter	National Forest											
			Custer	Gallatin	Deerlodge	Helena	Beaverhead	Lolo	Bitterroot	Flathead	Kootenai	Nezperce	Clearwater	Kaniksu
		Inches	*Percent*											
ABLA/VASC	LP	3-6	31	10	17	15	17	14	10	10	8	13	4	8
ABLA/XETE		6-10	58	34	39	34	45	38	37	34	36	31	13	16
		10-20	11	53	37	49	36	46	43	44	56	49	47	69
		20+	0	3	7	2	2	2	9	11	0	7	36	7
			(33)	(285)	(607)	(615)	(1,001)	(444)	(159)	(422)	(311)	(397)	(349)	(121)
PSME/PHMA	DF	3-6	38	12	25	17	—	11	8	—	10	5	20	10
PSME/VAGL		6-10	29	30	40	36	—	27	18	—	19	11	27	19
		10-20	33	58	27	47	—	49	44	—	46	50	53	71
		20+	0	0	8	0	—	13	30	—	25	34	0	0
			(93)	(301)	(127)	(149)		(358)	(143)		(448)	(394)	(31)	(235)
THPL/CLUN	C-H	3-6	—	3	—	—	—	5	—	9	9	7	3	5
TSHE/CLUN		6-10	—	15	—	—	—	31	—	42	22	16	18	12
		10-20	—	36	—	—	—	56	—	49	45	46	52	48
		20+	—	46	—	—	—	8	—	0	24	31	27	35
				(47)				(122)		(119)	(1,203)	(228)	(910)	(1,473)
ABLA/CLUN	S-F	3-6	—	—	25	18	—	10	4	5	8	8	4	7
ABLA/MEFE		6-10	—	—	39	38	—	32	11	22	21	15	16	19
TSHE/MEFE		10-20	—	—	36	29	—	39	4	53	50	47	58	49
		20+	—	—	0	15	—	19	81	20	21	30	22	25
					(152)	(107)		(571)	(168)	(1,066)	(583)	(152)	(824)	(332)
ABGR/CLUN	L	3-6	—	9	—	—	—	8	—	8	5	4	3	—
		6-10	—	21	—	—	—	27	—	29	7	15	11	—
		10-20	—	22	—	—	—	59	—	63	62	48	43	—
		20+	—	48	—	—	—	6	—	0	26	33	43	—
				(82)				(139)		(321)	(136)	(395)	(212)	

[1]See appendix VIII for abbreviations for habitat types.
[2]1 = Limber pine (*Pinus flexilis;* ponderosa pine, and Douglas-fir/bunch grass types.
2 = Dry site Douglas-fir and moist site ponderosa pine.
3 = Moist site Douglas-fir.
4 = Cool sites dominated by lodgepine; dry, lower elevation subalpine fir.
5 = Moist site, lower elevation subalpine fir.
6 = Cold, moist site upper elevation subalpine fir.
7 = Warm, moist sites; mostly cedar-hemlock.

APPENDIX V

Stand Examination Fuel Summaries by National Forests

Stand examination summaries are biased toward stands designated for management activities. These stands tend to be high risk especially on some National Forests. Loadings of downed woody material and duff depths are summarized in tables 14; and location of samples in table 15.

Table 14.—Means and standard deviations from Stand Examinations by National Forest of downed woody material loadings and duff depths

Cover type	Downed woody material: 0.25 to 1 inch Mean	0.25 to 1 inch S.D.	1 to 3 inches Mean	1 to 3 inches S.D.	Large Mean	Large S.D.	Total Mean	Duff depth Mean	Duff depth S.D.	Number sample points	Rotten
	Tons/acre							*Inches*			*Percent*
					Beaverhead National Forest						
DF	1.8	2.6	3.7	8.7	10.8	12.2	16	1.2	0.7	275	72
LP	1.5	2.6	3.7	8.0	17.7	21.1	23	1.2	.9	1,761	51
S-F	1.7	2.8	3.3	6.1	26.9	25.1	32	2.5	1.7	238	53
					Bitterroot National Forest						
PP	.8	1.0	1.4	1.8	11.3	13.6	14	.8	.6	1,685	69
DF	1.6	1.8	2.0	1.8	21.1	19.0	25	1.2	.9	7,158	67
LP	1.0	1.8	1.9	1.6	25.9	21.4	29	1.4	.9	1,152	62
S-F	1.7	2.7	2.2	1.8	51.2	21.2	55	2.3	1.4	471	56
					Clearwater National Forest						
PP	1.6	1.4	2.4	1.6	9.7	10.8	14	.4	.2	317	56
DF	1.5	1.2	2.5	1.8	22.6	19.1	27	1.2	.8	6,450	62
LP	1.0	.8	1.8	1.6	19.7	17.7	22	.9	.7	1,329	56
L	1.4	.9	2.4	1.9	31.0	25.1	35	1.2	.8	9,403	60
S-F	1.3	1.5	2.0	1.8	32.0	21.1	35	1.3	.9	6,381	64
C-H	1.5	1.0	2.6	2.3	39.2	27.7	43	1.6	1.0	6,753	57
WP	1.1	.8	2.1	2.1	29.4	22.3	33	1.1	.7	588	55
					Custer National Forest						
PP	2.1	1.6	2.3	3.8	6.9	6.6	11	1.0	.5	1,732	35
					Deerlodge National Forest						
DF	1.3	1.4	2.1	2.1	10.0	11.3	13	1.0	.6	757	62
LP	.9	.8	2.2	2.2	13.8	19.1	17	1.0	.7	2,486	54
S-F	.9	.9	2.6	2.2	24.9	24.0	28	1.5	.9	215	62
					Flathead National Forest						
PP	.7	.6	1.1	1.1	9.5	13.1	11	.9	.8	415	55
DF	1.0	.9	2.0	2.1	16.4	18.3	19	1.4	1.1	5,094	57
LP	1.0	.9	2.6	2.6	12.4	13.7	16	1.3	1.1	3,884	46
L	1.1	1.1	2.0	2.3	19.3	20.1	22	1.7	1.4	4,342	52
S-F	1.4	1.4	2.8	3.1	32.5	27.2	37	2.1	1.5	7,303	52
C-H	1.4	1.3	2.6	2.1	33.2	29.9	37	2.4	1.2	349	63
WP	1.2	.9	2.7	3.1	25.0	27.1	29	2.0	1.4	196	58
					Gallatin National Forest						
DF	2.1	1.9	2.5	2.4	15.2	16.0	20	1.5	.7	459	59
LP	1.2	.7	1.8	2.0	19.9	31.4	23	1.7	.9	676	43
S-F	1.5	1.0	2.9	2.1	21.0	13.4	25	2.6	1.2	152	56
					Helena National Forest						
PP	0.9	0.7	1.4	1.6	2.3	2.6	5	0.5	0.4	193	76
DF	1.1	1.1	3.0	2.8	16.0	14.7	20	.8	.6	2,836	48
LP	.8	.6	2.0	1.6	13.0	10.7	16	1.1	.7	2,104	52
S-F	1.3	.8	3.6	2.3	27.3	16.5	32	1.3	1.1	458	54
					Idaho Panhandle National Forests						
PP	1.1	.9	1.8	1.8	12.3	14.6	15	1.1	.7	822	53
DF	1.5	1.3	2.7	2.6	16.0	17.1	20	1.3	.8	6,567	53
LP	1.4	1.4	2.6	2.4	14.3	17.7	18	1.3	.8	3,317	49
L	1.5	1.2	2.9	2.3	28.2	35.8	33	1.4	.9	7,222	62
S-F	1.3	.9	2.6	2.4	29.5	29.6	33	1.6	1.0	5,888	52
C-H	1.4	1.2	2.8	2.4	34.3	27.0	38	1.8	1.1	7,744	55
WP	1.3	1.5	2.2	2.5	20.0	20.3	24	1.4	.8	1,226	54
					Kootenai National Forest						
DF	2.3	2.4	2.8	2.2	12.2	9.0	17	1.5	1.1	1,703	—
LP	1.2	.9	2.9	3.1	12.5	9.9	17	2.6	2.0	65	—
L	2.9	2.9	3.9	3.8	24.1	26.0	31	2.2	1.9	472	—
S-F	1.5	1.8	1.9	2.0	27.9	20.3	31	1.8	1.3	582	—
C-H	4.8	3.5	6.8	5.9	33.5	27.8	45	2.0	1.4	224	—
					Lewis and Clark National Forest						
PP	1.0	.4	1.3	.8	5.4	6.3	8	.8	.5	151	64
DF	4.5	4.7	5.3	7.4	19.9	18.4	30	1.2	.7	572	53
LP	2.5	1.7	3.7	4.2	17.4	13.4	24	.6	.7	1,716	36
S-F	3.5	4.2	2.7	2.4	29.2	9.7	35	1.2	1.0	86	23
					Lolo National Forest						
PP	0.9	0.6	1.1	1.2	10.4	9.3	12	0.6	0.8	665	—
DF	1.3	1.6	1.9	1.9	11.9	10.9	15	1.1	.6	4,233	—
LP	1.6	1.3	2.4	1.8	15.8	12.6	20	1.1	.7	1,591	—
L	1.8	1.3	2.4	1.7	17.5	17.3	22	1.6	.7	848	—
S-F	1.8	1.3	2.7	2.6	36.3	23.4	41	1.4	.9	767	—
					Nezperce National Forest						
PP	2.6	3.3	3.1	2.4	20.8	8.7	26	.8	.5	140	62
DF	2.0	1.7	3.1	2.9	17.1	19.4	22	1.3	.8	875	56
LP	1.1	.7	2.3	1.9	13.2	14.1	17	1.4	.6	1,506	45
L	1.9	1.9	2.6	2.6	28.4	54.4	33	1.5	1.0	3,109	33
S-F	1.5	1.9	2.0	2.2	25.3	18.6	29	1.3	.9	451	61
C-H	2.1	2.3	4.0	3.1	32.7	27.1	39	1.7	1.2	445	57

Table 15.—Number of stands sampled by Forest and Ranger District (R.D.) using Stand Examinations

Westside Forests

National Forest	Cover type[1] DF	S-F	LP	C-H	L	PP
BITTERROOT:						
Darby R.D.	130	12	16		3	66
Stevensville R.D.	59	8	29		3	25
Sula R.D.	674	43	100			113
West Fork R.D.	77		5			11
CLEARWATER:						
Canyon R.D.	154	26	3	206	349	
Kelly Creek R.D.	54	71	46	103	87	
Lochsa R.D.	61	27		36	85	12
Palouse R.D.	47	4	6	48	100	2
Pierce R.D.	52	20	12	161	154	1
Powell R.D.	194	357	37	79	95	2
FLATHEAD:						
Condon R.D.	116	137	106	25	120	28
Glacier View R.D.	58	302	103	2	82	
Hungry Horse R.D.	25	196	25		65	
Spotted Bear R.D.	88	97	71		38	1
Swan Lake R.D.	509	120	234	24	336	38
Tally Lake R.D.	73	104	110		26	
KOOTENAI:						
Fortine R.D.	119	58	8	3	33	
Troy R.D.	63	12	1	34	30	3
LOLO:						
Missoula R.D.	182	30	48		25	23
Ninemile R.D.	132	16	41	2	35	25
Plains R.D.	18	3	18		6	3
Seeley R.D.	29	14	14		7	1
Superior R.D.	9	1	1		1	2
Thompson Flats R.D.	24	2	110		6	8
NEZPERCE:						
Clearwater R.D.	9	1	3		51	11
Elk City R.D.	48	12	75		118	
Red River R.D.	12	19	80		36	1
Salmon R.D.	9	4	2		8	
Selway R.D.	54	31	1	97	145	
IDAHO PANHANDLE:						
Avery R.D.	8	39	1	37	22	
Fernan R.D.	10		4		15	7
Sandpoint R.D.	120	45	34	72	37	11
St. Maries R.D.	93	81	33	146	267	7

Eastside Forests

National Forest	Cover type[1] DF	S-F	LP	C-H	L	PP
BEAVERHEAD:						
Dillion R.D.	48	43	258			
Wisdon R.D.		13				
Wise River R.D.	4	2	21			
CUSTER:						
Ashland R.D.						50
Districts R.D.						73
Sioux R.D.						36
DEERLODGE:						
Butte R.D.	20	1	44			
Deerlodge R.D.	25	13	70			
Jefferson R.D.		5	49			
Philipsburg R.D.	58	17	151			
GALLATIN:						
Big Timber R.D.	42		3			
Bozeman R.D.	17	9	41			
Gardiner R.D.	15	12	57			
Hebgen Lake R.D.		2	11			
Livingston R.D.	3		1			
HELENA:						
District-3 R.D.	67	11	78			4
Helena R.D.	40	3	1			8
Lincoln R.D.	34	6	40	1		
Townsend R.D.	69	3	75			1
LEWIS & CLARK						
Belt Creek R.D.	6		2			1
Judith R.D.	20	4	118			3
Musselshell R.D.	28		16			11
White Sulphur R.D.	27	3	39			

[1]DF = Douglas-fir.
S-F = Engelman spruce-subalpine.
LP = Lodgepole pine.
C-H = Western redcedar-western hemlock.
L = Western larch-grand fir.
PP = Ponderosa pine.

APPENDIX VI

Volumes of Large Downed Woody Material

Table 16, summarizing volumes by cover type, was based on volumes per acre in table 4 and commercial forest acreages (see footnote 1). Volumes for the white pine type were computed using the downed woody volume per acre for cedar-hemlock. Volumes per acre for western Montana were averaged from data on the Bitterroot, Lolo, Flathead, and Kootenai National Forests. For northern Idaho, they were averaged from data on the Kaniksu, St. Joe, Clearwater, and Nezperce National Forests.

APPENDIX VIII

Habitat Types

Common Name	Scientific Name	Abbreviation	ADP Code
ponderosa pine/Idaho fescue	*Pinus ponderosa/Festuca idahoensis*	PIPO/FEID	140
ponderosa pine/bluestem	*Pinus ponderosa/Andropogon* spp	PIPO/AND	110
limber pine/common juniper	*Pinus flexilis/Juniperus communis*	PIFI/JUCO	070
limber pine/Idaho fescue	*Pinus flexilis/Festuca idahoensis*	PIFL/FEID	050
ponderosa pine/bitterbrush	*Pinus ponderosa/Purshia tridentata*	PIPO/PUTR	160
limber pine/bluebunch wheatgrass	*Pinus flexilis/Agropyron spicatum*	PIFL/AGSP	040
Douglas-fir/pinegrass	*Pseudotsuga menziesii/Calamagrostis rubescens*	PSME/CARU	320
Douglas-fir/Idaho fescue	*Pseudotsuga menziesii/Festuca idahoensis*	PSME/FEID	220
Douglas-fir/bluebunch wheatgrass	*Pseudotsuga menziesii/Agropyron spicatum*	PSME/AGSP	210
Douglas-fir/rough fescue	*Pseudotsuga menziesii/Festuca scabrella*	PSME/FESC	230
Douglas-fir/elk sedge	*Pseudotsuga menziesii/Carex geyeri*	PSME/CAGE	330
Douglas-fir/kinnikinnick	*Pseudotsuga menziesii/Arctostaphylos uva-ursi*	PSME/ARUV	350
Douglas-fir/white spiraea	*Pseudotsuga menziesii/Spiraea betulifolia*	PSME/SPBE	340
ponderosa pine/bluebunch wheatgrass	*Pinus ponderosa/Agropyron spicatum*	PIPO/AGSP	130
ponderosa pine/snowberry	*Pinus ponderosa/Symphoricarpos albus*	PIPO/SYAL	170
Douglas-fir/common juniper	*Pseudotsuga menziesii/Juniperus communis*	PSME/JUCO	360
ponderosa pine/chokecherry	*Pinus ponderosa/Prunus virginiana*	PIPO/PRVI	180
Douglas-fir/heartleaf arnica	*Pseudotsuga menziesii/Arnica cordifolia*	PSME/ARCO	370
Douglas-fir/ninebark	*Pseudotsuga menziesii/Physocarpus malvaceus*	PSME/PHMA	260
Douglas-fir/blue huckleberry	*Pseudotsuga menziesii/Vaccinium globulare*	PSME/VAGL	280
Douglas-fir/snowberry	*Pseudotsuga menziesii/Symphoricarpos albus*	PSME/SYAL	310
Douglas-fir/twinflower	*Pseudotsuga menziesii/Linnaea borealis*	PSME/LIBO	290
Douglas-fir/dwarf huckleberry	*Pseudotsuga menziesii/Vaccinium caespitosum*	PSME/VACA	250
subalpine fir/beargrass	*Abies lasiocarpa/Xerophyllum tenax*	ALBA/XETE	690
grand fir/beargrass	*Abies grandis/Xerophyllum tenax*	ABGR/XETE	510
subalpine fir/grouse whortleberry	*Abies lasiocarpa/Vaccinium scoparium*	ABLA/VASC	730
nmountain hemlock/beargrass	*Tsuga mertensiana/Xerophyllum tenax*	TSME/XETE	710
subalpine fir/dwarf huckleberry	*Abies lasiocarpa/Vaccinium caespitosum*	ABLA/VACA	640
spruce/twinflower	*Picea/Linnaea borealis*	PICEA/LIBO	470
subalpine fir/blue huckleberry	*Abies lasiocarpa/Viccinium globulare*	ABLA/VAGL	720
spruce/dwarf huckleberry	*Picea/Vaccinium caespitosum*	PICEA/VACA	450
subalpine fir/pinegrass	*Abies lasiocarpa/Calamagrostis rubescens*	ABLA/CARU	750
subalpine fir/virgin's bower	*Abies lasiocarpa/Clematis pseudoalpina*	ABLA/CLPS	770
subalpine fir/heartleaf arnica	*Abies lasiocarpa/Arnica cordifolia*	ABLA/ARCO	780
lodgepole pine series	*Pinus contorta* series	PICO SERIES	910 920 930 940 950
spruce/starry Solomon's seal	*Picea/Smilacina stellata*	PICEA/SMST	480
spruce/ninebark	*Picea/Physocarpus malvaceus*	PICEA/PHMA	430
subalpine fir/elk sedge	*Abies lasiocarpa/Carex geyeri*	ABLA/CAGE	790
subalpine fir/queencup beadlily	*Abies lasiocarpa/Clintonia uniflora*	ABLA/CLUN	620
subalpine fir/menziesia	*Abies lasiocarpa/Menziesia ferruginea*	ABLA/MEFE	670
western hemlock/menziesia	*Tsuga heterophylla/Menziesia ferruginea*	TSME/MEFE	680
subalpine fir/twinflower	*Abies lasiocarpa/Linnaea borealis*	ABLA/LIBO	660
subalpine fir/Sitka alder	*Abies lasiocarpa/Alnus sinuata*	ABLA/ALSI	740
spruce/queencup beadlily	*Picea/Clintonia uniflora*	PICEA/CLUN	420
subalpine fir/sweetscented bedstraw	*Abies lasiocarpa/Galium triflorum*	ABLA/GATR	630
subalpine fir/bluejoint	*Abies lasiocarpa/Calamagrostis canadensis*	ABLA/CACA	650
Picea/sweetscented bedstraw	*Picea/Galium trifolium*	PICEA/GATR	440
subalpine fir/smooth wood-rush	*Abies lasiocarpa/Luzula hitchcockii*	ABLA/LUHI	830
whitebark pine-subalpine fir	*Pinus albicaulis-Abies lasiocarpa*	PIAL/ABLA	850
subalpine fir/mountain gooseberry	*Abies lasiocarpa/Ribes montigenum*	ABLA/RIMO	810
subalpine fir-whitebark pine/ grouse whortleberry	*Abies Lasiocarpa-Pinus albicaulis/ Vaccinium scoparium*	ABLA/PIAL/ VASC	820
whitebark pine-subalpine fir	*Pinus albicaulis-Abies lasiocarpa*	PIAL/ABLA	850
spruce/cleftleaf groundsel	*Picea/Senecio streptanthifolius*	PICEA/SEST	460
whitebark pine	*Pinus albicaulis*	PIAL	870
alpine larch-subalpine fir	*Larix lyallii-Abies lasiocarpa*	LALY/ABLA	860
western redcedar/queencup beadlily	*Thuja plicata/Clintonia uniflora*	THPL/CLUN	530
western hemlock/queencup beadlily	*Tsuga heterophylla/Clintonia uniflora*	TSHE/CLUN	570
grand fir/queencup beadlily	*Abies grandis/Clintonia ulflora*	ABGR/CLUN	520
western redcedar/devil's club	*Thuja plicata/Oplopanax horridum*	THPL/OPHO	550

Brown, James K., and Thomas E. See.
1981. Downed dead woody fuel and biomass in the Northern Rocky Mountains. USDA For. Serv. Gen. Tech. Rep. INT-117 48 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Weights and volumes of downed woody material in diameter classes of one-fourth to 1, 1 to 3, and greater than 3 inches and forest floor duff depths were summarized from extensive inventories in northern Idaho and Montana. Biomass loadings are shown by cover types and habitat types within National Forests. Total downed woody biomass ranged from 5 tons per acre in ponderosa pine to 33 tons per acre in cedar-hemlock. Relationships for predicting loading from stand age, slope, aspect, and elevation proved ineffectual. Loadings generally increased with increased productivity, but varied greatly with stand age. Fuels tended to become predictably high in overmature stands but unpredictable in young, immature, and mature stands. Forest fuel succession is discussed in relation to tree mortality, fuel buildup, and depletion.

KEYWORDS: forest fuels, biomass, fuel accumulation, forest utilization, forest inventory